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ABSTRACT

This is the second book in a sequence of four volumes written and designed for parents of students of science, particularly for those at the lower and upper elementary and junior high or intermediate level, senior high students, college students preparing to teach science, and all those individuals who are interested in science and the application of science in daily life. This volume consists of seven chapters that contain 125 discrepant events (occurrences or happenings which go against what we usually think likely) dealing with different types or forms of energy and the transformation from one into the other. Each of the chapters contains demonstrations that can be used to build lessons dealing with the sources of energy, heat, magnetism, static electricity, current electricity, light, and sound. Instructions for each event include materials, procedure, questions, and an explanation. Emphasis is placed on the use of simple materials. A list of available science educational materials from Science Inquiry Enterprises is included and an index is provided. (LZ)

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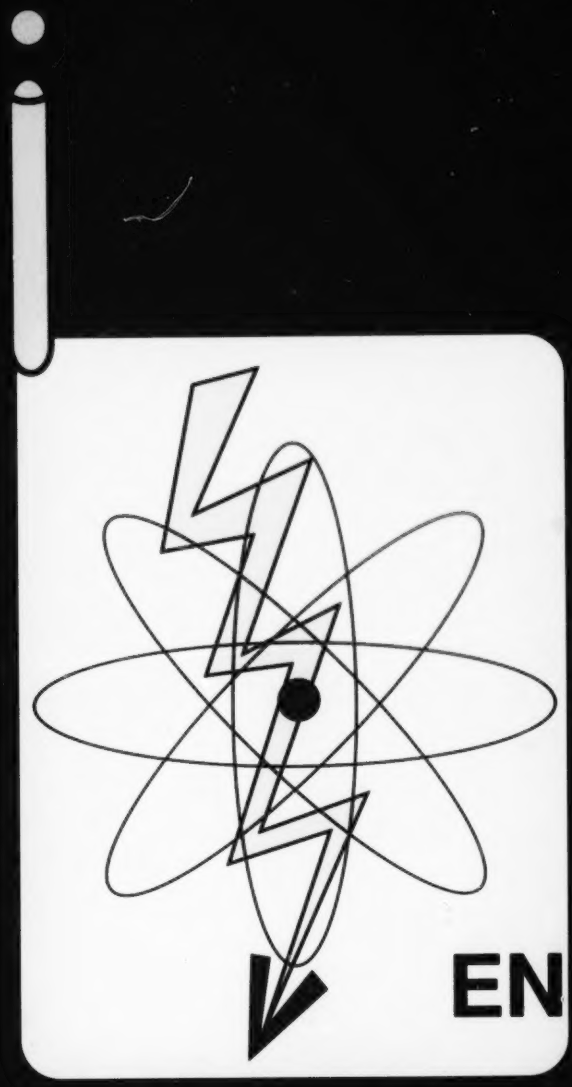

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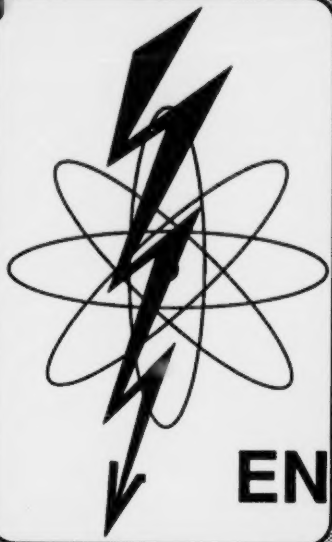
Turning Kids On To SCIENCE

IN THE HOME



BOOK 2

ENERGY

Easy to follow recipes for doing 120 science activities on Heat, Magnetism, Electricity, Light, & Sound with very simple materials found in and around the house.

Dr. Tik L. Liem

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Book 2 - ENERGY"

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TO THOSE PARENTS
WHO WANT TO PUT MORE *Excitement*
IN THEIR CHILDREN'S LIFE

CAUTION

- Only with adult supervision may children use this book!
- Fire may only be used with adult supervision!
  All fire hazardous events are marked with this symbol: 🔥
- Chemicals and/or electricity may only be used under adult supervision!
  Never touch chemicals with your bare fingers: poisonous chemicals can even be absorbed through the skin!
  Hazardous events involving chemicals are all marked with: ☠
- The use of chemicals always brings with it some hazards. It can be dangerous, but when handled properly it can be lots of fun!
- When working with a flame or when a flame is involved in an event, always have a carbondioxide or Halon fire extinguisher at hand.
- Always follow instructions - the "How to do it" - very carefully!
- Never work all by yourself. Always have someone with you ready to turn the fire or electricity off, if something goes wrong.
- The author of **"Turning Kids On To Science In The Home"** is not responsible for any accidents resulting from irresponsible or incompetent use of the demonstrations and activities suggested in this book.
- Although some events are rather dangerous, but if the instructions are carefully followed, they can give you a lot of joyful moments!

So, have lots of fun!

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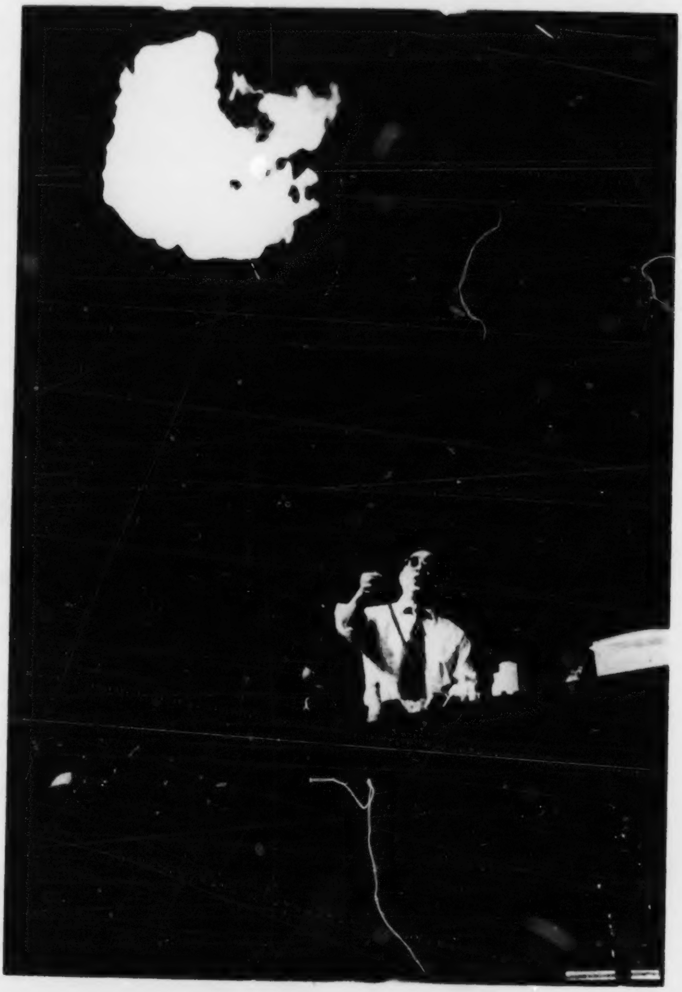
Be an

Excellent Example



for your children to model after !

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INTRODUCTION to BOOK 2

This book is the second book to a sequence of four volumes, written and designed for parents of students of science, particularly for those at the lower and upper elementary, and junior high or intermediate level, for senior high students, for college students preparing to teach science, and for all those individuals who are interested in science and the application of science in our daily life.

In this space age where science plays a major role in determining whether a country or even a personal life will be able to advance or progress, I feel that the understanding of science concepts and science principles will strongly help towards this goal. Statistics and test results have shown that American youngsters can't perform the simplest technical functions. A recent report of a study done by the Educational Testing Service in Princeton, New Jersey mentioned that American nine-graders were compared with same age level children of five other countries and four Canadian provinces, and they came out on the bottom in mathematics and very near the bottom in science! This is very sad news, even worse is their prediction that in the year 2000 there will be a shortage of close to a quarter million engineers, physicists, chemists, and biologists in the USA.

Where lies the problem? What makes the USA so lagging behind other countries, like: Japan, Western European countries, and in recent years some of the Pacific Rim countries? This lagging is not only economically, but especially in academic achievements of students in the field of mathematics and science! Could it lie in the way math and science is being taught in our schools? Could it lie in the way math and science is being presented to our young children? These questions come up in my mind when too many children I talked to said, that they do not like math and science in their schools. Could the problem be that school teachers do not have enough background in mathematics and science? And because of this, that they are conveying the message to students that math and science are a chore and really not fun to study? Could it be that schools do not have enough materials for doing science? Could it be that at home, our young children are also not getting any encouragement from their parents to go in the fields of science and mathematics?

I think it is a combination of all those mentioned, especially I think that not enough **enthusiasm** in science is being shown in the home as well as in the schools. If teachers as well as parents of students can show more excitement and **enthusiasm in science**, and not be afraid to actually show their enjoyment in doing science in front of the children, there is no doubt in my mind that more of our younger people will find science exciting, and continue studying in the field of science!

In the teaching of a science concept, it is most essential for the teacher to arouse the students' curiosity. Unless the student wants to know what the teacher has to say, it is most likely that time and effort in trying to teach the student would have been completely wasted. The first task of a teacher is to attract the attention of the student. This goes for all levels of learning, whether it is primary grade or college. A student without interest is the desperation of any teacher. In fact, the main objective of formal education is the arousing of the students' interest, if nothing else. Once curiosity is aroused the student will learn much more on his/her own than the teacher can ever teach him/her. Learning only takes place if the student wants to learn!

In this book the description of each of the **exciting events** is organized in such a way as to provide the user with the maximum guidance for conducting a science inquiry lesson. Emphasis has been placed on the use of simple material so that most of the events may be carried out with things that are found in everyday life or may be bought in local stores.

When you as a parent, use this book, you are actually becoming your child's or children's own private teacher! Isn't that exciting! All the statements concerning the teacher apply therefore, to you as well. The questions are there for each of the **exciting events** to be posed to the learner. The explanation is always there on each of the pages to give you the support you need in answering the questions. You can, of course, add your own questions if you want to go into more depth in each of the events.

The use of exciting events in the teaching of science is one of the best methods to arouse interest and curiosity. These **exciting events**, sometimes also called **discrepant events**, mind-capturing, or intuition-offending, are occurrences or happenings which go against what we usually think likely. Each of the events is set up in such a way that it poses a question to the student and asks him/her to come up with the explanation. There is evidence that students will remember science concepts longer when they were engaged in experiencing **exciting events**. This series of books is a collection of thoroughly tested **exciting events**. They can be used to start a lesson in almost any topic of science at the elementary or secondary level. They can also be used as reinforcement activities in the homes or as challenging problems for further inquiry. Each of the events is a focus for inquiry teaching, a most appropriate way of reflecting the true nature of science in the homes. The students are required to put into practice most of the science processes when engaged in inquiry.

The science concepts in this series of books are organized in such a way that it makes most sense:
Book 1: **Our Environment**, consisting of the chapters: Air, Flowing Air, Weather, Characteristics of Matter, and Chemicals in our Environment.
Book 2: **Energy**, consisting of the chapters: Forms of Energy, Heat, Magnetism, Static & Current Electricity, Light, and Sound.
Book 3: **Forces & Motion**, containing chapters: Forces Affecting Things, Forces and Principles in Space Science, Some Phenomena in Earth Science.
Book 4: **Living Things**, containing the chapters: Plants, and Human Biology.

In order to make it easier to find where certain topics are being dealt with, each of the books has its own **table of contents** in the front and an **index** in the back of the book. **Introductions** are placed in front of each book, so that each of the books can be used independently from each other.

INSTRUCTIONS FOR PARENTS

Please follow these instructions for the Teaching Procedure in using **Turning Kids On To Science in the Home** as close as possible, so that your lesson will be most effective:

1. Presentation :
   Present to the learner or involve the learner with the **exciting event** by describing or commenting on the names of objects and operations only and not mentioning the reasons for the occurrence. In other words, you may tell the student what you are doing and what materials you are handling, but not the reason why something is happening.

2. Interaction:
   Ask the learner questions that eventually will lead him/her to the main reason for the occurrence. In doing this, the students will be engaged in science inquiry and actually practicing the science processes of observing, measuring, inferring, predicting, interpreting data, identifying and controlling variables, hypothesizing, and experimenting.

3. Involvement:
   Participate the learner in similar (and simpler) **exciting events** or exciting activities, that are based on and illustrating the same science concept. This will reinforce the learning and retention of that particular concept. Students may work individually or together with you.

It is essential that the presentation of the **exciting event** or the involvement of the students in the event takes place under the following conditions. Think of giving the student: **INSIGHT!**

IN = Arouse Interest
The event should confront the student with a perplexing problem. It should be presented almost like the way a magician would do a magic act.

S I = Use Simple Materials
The event should be performed with materials that are familiar to the student, in other words use simple materials that can be found in daily life.

G = Use all Gateways
Use all the gateways into the brain, meaning students should have the opportunity to observe as well as carry out the events themselves. They should be allowed to totally experience the exciting event (by using all five senses).

H = Hinge it with Examples
When dealing with the concept underlying the event, examples and applications of the concept in our daily life should be mentioned to make it more meaningful to the student.

T = Tie it all together with Joy and Enthusiasm
Show genuine enthusiasm in presenting the puzzling event and don't be afraid to show your own enjoyment in the subject matter in general!

ENJOY YOURSELVES !

BOOK 2

ENERGY

This volume consists of seven chapters dealing with the different types or forms of energy and the transformation from one into the other. Each of the chapters contains demonstrations that can be used to start off lessons dealing with the sources of energy, heat, magnetism, static and current electricity, light and sound.

Chapter 1 deals with how heat compares with temperature, heat of fusion and vaporization, the sources of energy: chemical, mechanical, heat energy, and nuclear energy, and how they could be transformed from one into the other. It also deals with potential versus kinetic energy.

Chapter 2 deals with heat and how it travels. It moves from one place to the other by conduction in solids, by convection in fluids, and by radiation through fluids and vacuums. Heat makes solids, liquids, and gases expand.

Chapter 3 contains demonstrations to show the characteristics of magnets, the nature of magnetism, and the rules of magnetism. The construction of simple compasses, the showing of magnetic lines, and magnetic induction are dealt with in this chapter.

Chapter 4 should be used when dealing with static electricity. It deals with the attraction of uncharged objects, the positive and negative charges and how they attract or repel each other, the induction of static charges, and the storage of static charges in capacitors.

Chapter 5 deals with current electricity. The exciting events could be used to start lessons in conductivity, circuits, sources of electricity, and electromagnetism.

Chapter 6 contains exciting events to initiate lessons dealing with light, its reflection, refraction, and dispersion properties.

Chapter 7 deals with sound and its properties: the medium of travel, how loudness and pitch are influenced, the nature of resonance, and its velocity in air.

Arousing *Interest* is the First Task of a GOOD TEACHER

THE MAGIC CUP

Showing that air expands when heated and that air exerts pressure.

CHAPTER 1

WHAT FORMS OF ENERGY ARE THERE ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

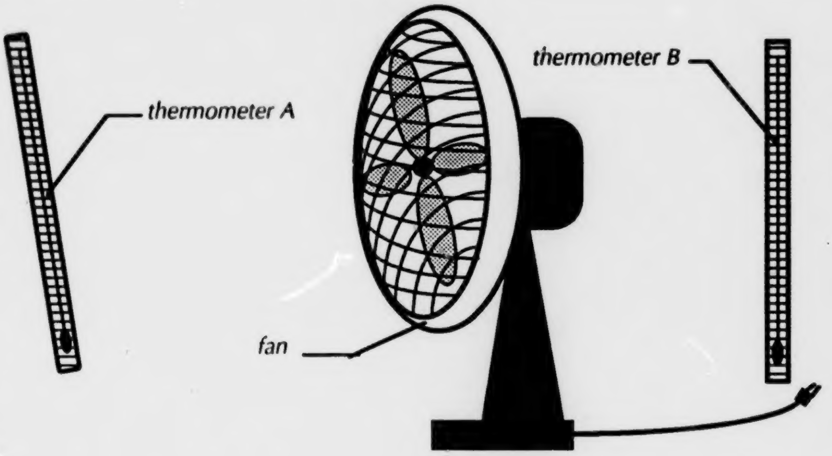
a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

— The ability to hold heat depends on the mass and material of the object.
— Temperature is a measure of how hot or cold an object or substance is.
— Heat is required to change a solid into a liquid, a liquid into a gas, or a solid into a gas.
— Energy can be developed from chemical, mechanical, magnetic, or nuclear sources.
— All forms of energy can be transformed from one form into the other.
— All forms of energy can be traced back to solar energy.

2.1.03. WARMING BREEZES

What you need: 1. A small electric fan. 2. Two identical thermometers.



How to set it up

1. Show the students the two identical thermometers A and B, and let two students read the temperature of each of the thermometers.
2. Place thermometer A in the breeze of the fan and thermometer B near the fan, but not in the breeze.
3. Ask the students: "Which of the two thermometers will show a lower temperature?" (Anticipated answer: Thermometer A).
4. After leaving the fan on for several minutes and leaving the two thermometers in the two designated places, have two other students read off the two temperatures.

What questions to ask

1. Which of the two thermometers do you predict will show a lower temperature? The one in the breeze or the one not in the breeze?
2. What temperature did the two thermometers show?
3. Why was there no difference in temperature?
4. What causes the cool feeling on our skin in a breeze?
5. What would you predict would happen to temperatures A and B if the bulbs of the thermometers were moistened?

How to explain it:

Most of the students will predict that thermometer A will show a lower **temperature**. Actually, both temperatures stay the same. A very sensitive thermometer might even show that spot A (the one in the breeze) is slightly warmer than spot B, since the motor of the fan gets a little warmer and this heat is carried in the wind stream. An additional reason for it to get a little warmer is the friction of air molecules colliding with the bulb.

The decrease in temperature in a breeze is only caused by the **evaporation of moisture.** For evaporation to occur, heat is needed. When heat is not supplied, this heat of evaporation is withdrawn from the liquid's surroundings, resulting in the decrease of temperature. If the thermometer bulbs were moistened, temperature A would show up much lower.

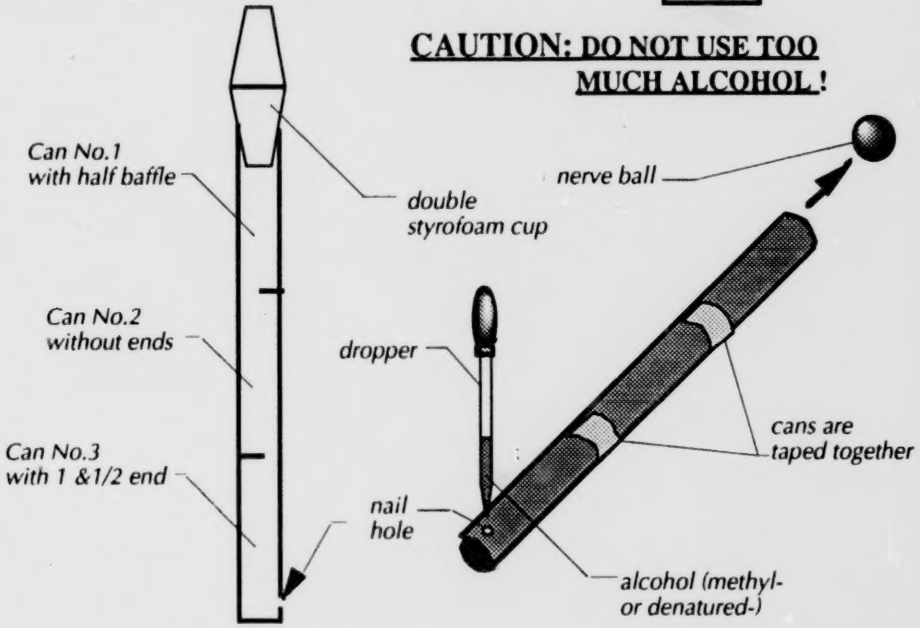
2.1.04. THE TIN-CAN BAZOOKA

What you need: 1. Three empty tin-cans (small V-8 or tomato juice).
2. Two styrofoam cups or a nerve ball (soft rubber foam).
3. Alcohol (methyl or ethyl, or gasoline) and a match.

How to set it up:

1. With a can opener cut open the ends of the tin-cans, except for one half-end of one can (top), and the bottom and one half of the other end of the third can (bottom can).
2. Connect the three (or four) cans on top of each other with masking tape.

CAUTION: DO NOT USE TOO MUCH ALCOHOL!



3. Punch a hole about 2 cm from the bottom, in the side of the bottom can about 1/2 cm in diameter (use a large nail).
4. Tape the two styrofoam cups together rim to rim, and place it tightly in the top opening (see Sketch) or squeeze the foam ball and insert it in the end of the tube.
5. Place two or three squirts of lighter fuel in the bottom hole and shake the stack of cans (let the fuel drip along the walls), and let it stand for a few seconds. You are now ready for ignition!
6. Strike a match and hold the flame close to the bottom opening (Watch out for the double cup cannon ball or the nerve ball!).

What questions to ask:

1. What are the two baffles in the 'cannon' for?
2. What purpose did the shaking of the stack of cans have?
3. What kind of energy resulted from the chemical explosion?
4. What other kinds of liquids do you think could be used in place of the alcohol?

How to explain it:

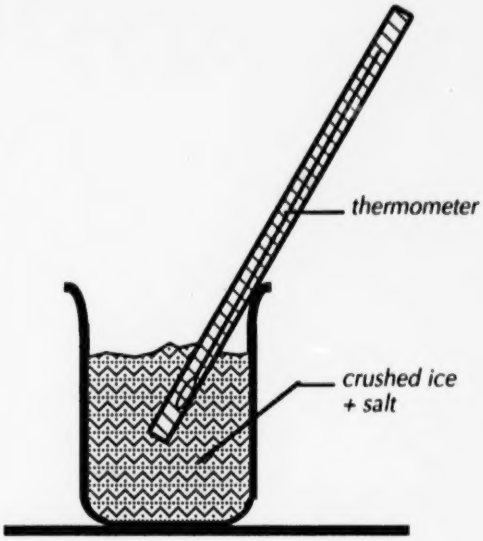
The baffles were left in the tin-can 'bazooka' to enhance the mixing of the fuel with the air in the cylinder. The shaking of the cylinder was done immediately after the fuel was injected for exactly the same reason. The better the mixture of fuel vapors and the air, the better the explosion. The **chemical energy** stored in the alcohol is transformed by the combustion into **kinetic energy** of the moving cannon ball. Gasoline or duplicating fluid or lighter fuel may be used instead of the alcohol. Even rubbing alcohol may work, except that a longer wait time is needed to let it evaporate before ignition.

2.1.02. MELTING ICE BELOW FREEZING ?

What you need: 1. A medium size beaker/ drinking glass & thermometer.
2. Common table salt, crushed ice.

How to set it up:

1. Fill the beaker/ drinking glass one-third full with crushed ice.
2. Pour 3 or 4 tablespoons of table salt in the center of the beaker on the crushed ice.
3. Cover this with another one-third beaker full of crushed ice.
4. Now show the students the beaker with crushed ice and ask: "At what temperature will ice melt?" (Anticipated answer: 'at 0° C').
5. Insert a thermometer in the ice and let a student read it off.



What questions to ask:

1. What is the thermometer reading of the melting ice?
2. At what temperature does ice usually melt?
3. What do you think made the ice melt below freezing point?
4. Does the melting process need heat or does it give off heat?
5. Was any heat supplied or withdrawn from the system?

How to explain it:

The **freezing** or **melting point** of salt water is much lower than that of pure water. The addition of salt to the ice at 0° C causes it to melt, because salt water cannot freeze at 0° C, just as pure water does not freeze at 5° C.

The melting process decreases the temperature because **melting needs heat,** and as heat was not supplied to the system of melting ice, it **withdraws heat** from its own environment. Just as the forced evaporation of liquid without any heat supply will have a cooling effect, this decrease in temperature is a result of a forced melting process.

The mixture of ice and salt is utilized in the production of home-made ice cream. The jacket of a glass container is filled with crushed ice and salt, which brings the temperature below freezing. The milk mixture is placed in the container and constantly stirred. Soon ice cream is formed, because of the low temperature it is placed in.

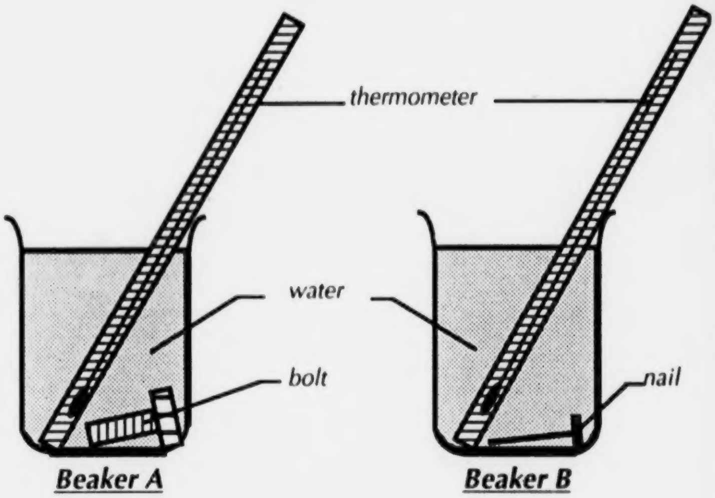
In colder climates, salt is used to melt ice on slippery roads in the winter. When temperatures go way down (below -10° C), however, adding salt does not help. The salt is then mixed with sand to increase the friction of tires on the road.

2.1.01. THE HOT BOLT

What you need: 1. A heavy steel bolt, a small iron nail.
2. Two identical beakers/drinking glasses, two thermometers.
3. One beaker or tin can (to boil water in).
4. A pair of tweezers or tongs.
5. Burner & stand, or hot plate/stove top.

How to set it up:

1. Place the bolt and nail together in a beaker or tin can in about 100 ml of water, heat over burner or hot plate and bring to a boil.
2. Pour 100 ml of water in each of the two identical beakers and read their temperature off with the thermometer.
3. Transfer the bolt to beaker A and the nail to beaker B with the tongs.
4. Read off the temperature in each of the beakers every 15 seconds until the temperature starts to level off (have a student assist you).



What questions to ask:

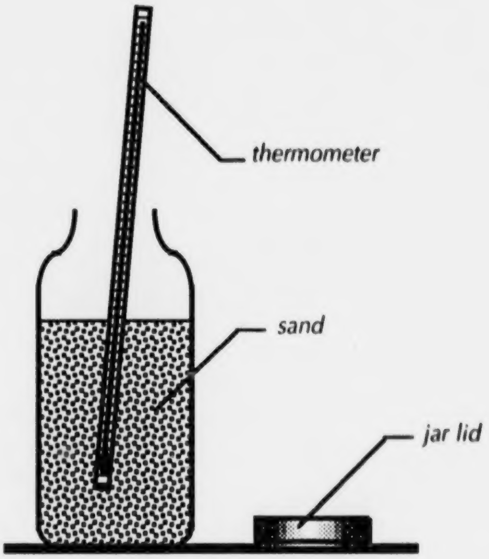
1. What is the temperature of the boiling water?
2. What is the temperature of the bolt and nail before the transfer?
3. In which of the two beakers did the temperature rise higher?
4. Why did the water in the two beakers rise in temperature?
5. Which has a higher heat capacity, the bolt or the nail?
6. What determines the ability for an object to hold heat (heat capacity)?

How to explain it

The water is boiling at 100° C, at normal pressure. The bolt and the nail that were in the same water, have also the same **temperature** of 100° C before they were transferred to Beaker A & B, but they did not **absorb** the same amount of heat. The large bolt holds more heat or its **heat capacity** is higher, because it is larger in mass compared to the nail. The extra heat is enough to raise the temperature of the water in *Beaker A* more than that in *Beaker B*. The ability to hold heat or the heat capacity of an object is determined by its mass and the material it is made of. Temperature is a measure of how hot or cold an object or substance is in degrees Celsius or Fahrenheit. Heat refers to the total energy of the moving molecules of a substance, measured in calories or BTU's (British Thermal Units).

2.1.05. WARM A BOTTLE BY SHAKING ?

What you need: 1. A medium size jar with lid
2. Dry sand (beach sand). 3. A thermometer.



How to set it up:
1. Fill the jar about two-thirds full with dry sand.
2. Push a thermometer in the sand and let one of the students read off the temperature.
3. Take the thermometer out of the jar, close the jar tightly and let the students take turns shaking the jar for 5 to 6 minutes in total (about 1/2 minute each for 10 to 12 students).
4. Open the jar after the shaking, push the thermometer in the sand and let a student read off the temperature again.

What questions to ask:
1. What were the temperature readings before and after the shaking?
2. What is the cause for the temperature to rise?
3. What type of energy was turned into heat?
4. To what type of energy as the original source can this produced heat be traced back?

How to explain it:

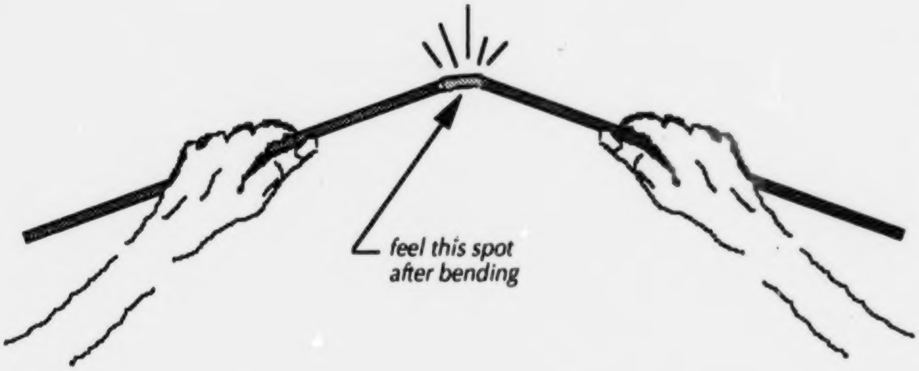
The shaking of the bottle or jar is **mechanical energy**, which was turned into **heat**. The mechanical shaking of the sand gave the sand particles **kinetic energy**, which caused friction between the sand particles, thus creating heat. The energy needed for the shaking of the jar was supplied by muscle power of the students. To give this energy, the students needed to eat (**chemical energy**), and the food the students ate came from plants and animals. The animals also needed to eat plants, and the plants in their turn obtained the energy from the sun to grow. All forms of energy can therefore be traced back to **solar energy.**

In this case, where the bottle of sand is actually passed on from one student to the other, or from child to parent and back, the heat of the persons' hands is actually passed on or transferred to the bottle of sand. This transfer of the heat from the hands may be prevented by insulating the jar with a cloth wrapped around it.

The forms of energy in this case can be traced back to solar energy:
Solar energy ---> Chemical energy (in plants) ---> Food (for animals & people) ---> Muscle power (person shaking bottle) ---> Mechanical energy (bottle moving) ---> Kinetic energy (sand grains colliding) ---> Friction ---> **Heat.**

2.1.06. THE WIRE HEATER

What you need: 1. A piece of heavy wire (coat hanger).
2. A wire cutter.



How to set it up:
1. Take a coat hanger and cut about a length of 30 cm piece off with the wire cutter.
2. Hold the two ends in each hand and bend the wire several times back and forth at the same spot.
3. Let students touch the spot that was bent, with their fingers.

What questions to ask:
1. Did the spot you touched feel warm or cold?
2. What type of energy was used to bend the wire?
3. What made the wire heat up (explain in terms of moving molecules)?
4. Would the same happen with a plastic or wooden rod?
5. What would eventually happen if we keep bending the wire?

How to explain it:

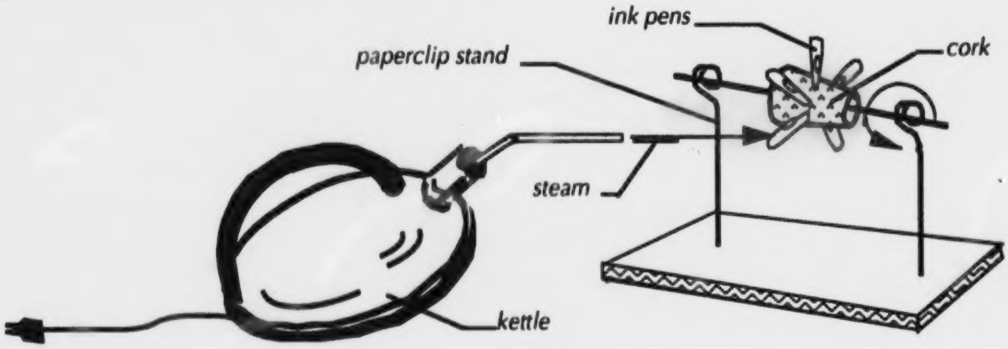
Bending the metal wire back and forth is actually putting **mechanical energy** from our muscles into the wire. This energy forces the molecules of metal to move faster at the bent spot and the friction of the faster moving molecules produces heat, thus causing the bent spot of the wire to feel warm to the touch. When this bending of the wire is continued, it will eventually break: this is called **metal fatigue.**

When using a plastic or wooden rod instead of a metal one, the bending can be carried on for a longer period before it breaks, because of the flexibility and elasticity of the material, unless it is bent beyond its flexibility point. The molecules here are not sliding past each other as much as in the metal wire, so that heat is not likely generated so readily.

2.1.07. USE HEAT TO TURN A WHEEL?

What you need: 1. A hot water kettle.

2. A fitting one-hole stopper for the kettle spout/ or a blob of clay.
3. A bent glass tube fitting in the stopper/ or a bendable straw.
4. A cork, 6 old ink pens, 4 paper clips.
5. A piece of soft wood or board.



How to set it up:

1. Fill the electric kettle with water and plug it in.
2. Insert the bent glass tube in the one-hole stopper and cover the kettle spout with the stopper. Or wrap the straw with clay and place it in the kettle spout.
3. Stick the six old ink pens (or any other small metal narrow plates) in the side of the cork and set up the cork to move freely as in the sketch, with modified paper clips as a stand on the wood board.
4. As soon as the water boils, direct the steam towards the lower or upper side of the cork against the baffles.

What questions to ask:

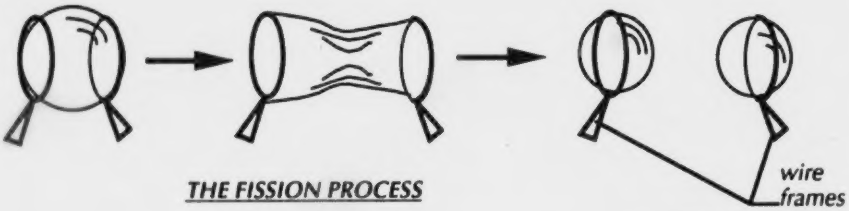
1. What is the original source of energy used to turn the wheel?
2. What forms of energy do we encounter in this event?
3. Where do we find this principle applied?
4. How is electricity produced and what could be the original form of energy that is transformed into electricity?

How to explain it:

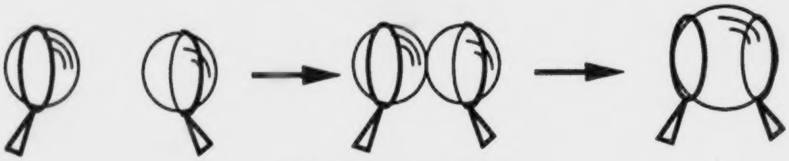
The original source of energy used is **electricity** for the electric kettle, which may be traced back to chemical sources or water power. The electricity is turned into **heat** in the heating coils of the kettle, which causes the water to boil and thus forming the steam. By leading this steam through a narrow tube, the vapor particles are pushed out with a velocity and thus gain in **kinetic energy**. In directing this steam flow to the scoops of the wheel, the kinetic energy is converted into **mechanical energy**. This finds application in the production of electricity in turning the turbo engines and in other steam engines.

2.1.08. FISSION AND FUSION

What you need: 1. Soap solution (1 part Joy, 2 parts glycerine, 3 parts water).
2. Two circular wire frames.
3. A wide shallow tray.



THE FISSION PROCESS



THE FUSION PROCESS

How to set it up

1. Place the soap solution in the shallow tray and dip the two circular wire frames in the solution.
2. Blow through the wire frame and blow a bubble with a diameter a little larger than the frame, and catch the bubble between the two frames.
3. Now stretch the bubble by pulling the two frames farther apart until the bubble separates into two bubbles in each frame (fission). When this is done a little faster a small bubble is released, illustrating the released neutron.
4. Bring the frames and the bubbles in it together; let the bubbles press against each other until they form one large bubble (fusion).

What questions to ask:

1. Why are bubbles always spherical in shape?
2. What is missing from this model of fission or fusion?
3. What examples can you give on nuclear energy sources in nature?
4. What are the dangers in the use of nuclear energy?

How to explain it:

This demonstration with the soap bubbles is only a **model** for the actual process of fission or fusion. In the case of **fission,** a very heavy nucleus splits and forms medium-weight nuclei. When two light-weight nuclei combine to form heavier, more stable nuclei, it is called **fusion.** The elements that are missing in the soap bubble model, are the neutrons and the energy released during fission, and the protons and energy released during fusion.

A nuclear source of energy in nature is the sun, where four hydrogen atoms fuse into one helium atom, and in the process of fusion it releases energy in the form of sunfihine.

The dangers in using nuclear energy lie in radiation leakages and the doses of radiation that the human being can withstand without being harmed.

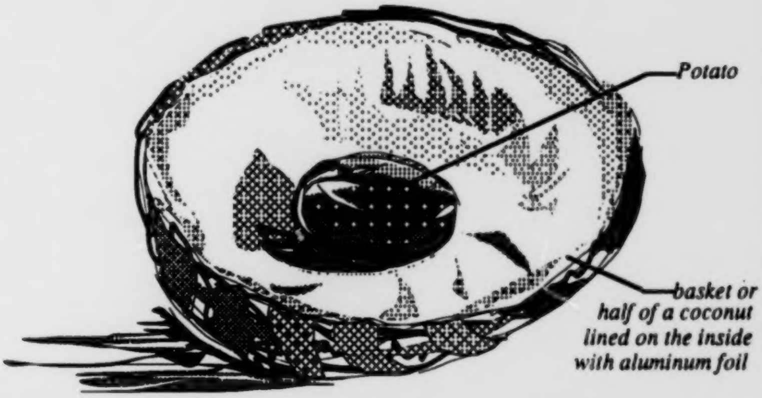
2.1.09 THE SUN-BAKED POTATO

Materials:
1. A round bread basket or half a coconut shell.
2. A small raw potato.
3. Aluminum foil (enough to line the basket).
4. A toothpick.

Procedure:

1. Take a piece of aluminum foil large enough to line the basket from the inside, and cover the inside of the basket with the foil - make sure the shiny side is showing.

2. Place a small raw potato in the center of the basket, and place the whole basket in the sun (do this preferably at a time when the sun shines at its hottest - between 11 am and 3 pm).


Potato
basket or half of a coconut lined on the inside with aluminum foil

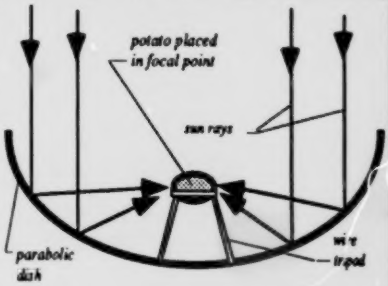
3. Leave this to bake for about 30 - 45 minutes and check the potato with the toothpick for softness (if the potato is done, it should be soft enought to pierce with the toothpick).

4. Pick a day that is wind still to do this. If there is some wind, place a cardboard shield around the basket. Make sure that no shadow falls on the basket!

Questions:
1. What is the function of the aluminum foil?
2. Does the shape of the basket have to be round? What other shapes can be used?
3. How can we make optimum use of the reflected sun rays?
4. At what spot do the sun rays come together? What is this spot called?
5. Would a larger or smaller basket be more effective in heating the potato?
6. Why do we carry out this event close to noon time? Why not early morning or late afternoon?
7. What process is actually happening on the sun to give off that much energy?
8. What forms of energy were the source and the end product?
9. What other ways are there to concentrate the energy from the sun?

Explanation: The original source of energy used is the sun's energy, which is nuclear, where four Hydrogen atoms are **fused** into one Helium atom. During this **fusion** process energy is radiated out in the form of sun rays. Only a small fraction of these sun rays falls on the earth, and again a very, very small fraction is falling on the basket. These sun rays are concentrated into a much smaller area by the shape of the basket and the reflecting aluminum foil, exactly where the potato is placed. The final form of energy is heat, which is cooking the potato. The larger the basket, the more sunrays it is catching, and thus the more effective it is in heating the potato. A basket in the shape of a parabolic disc would be the ideal shape, but the potato has then to be raised into the **focal point** of the disc. This can be achieved by placing the potato on a wire tripod. (see Sketch on right).

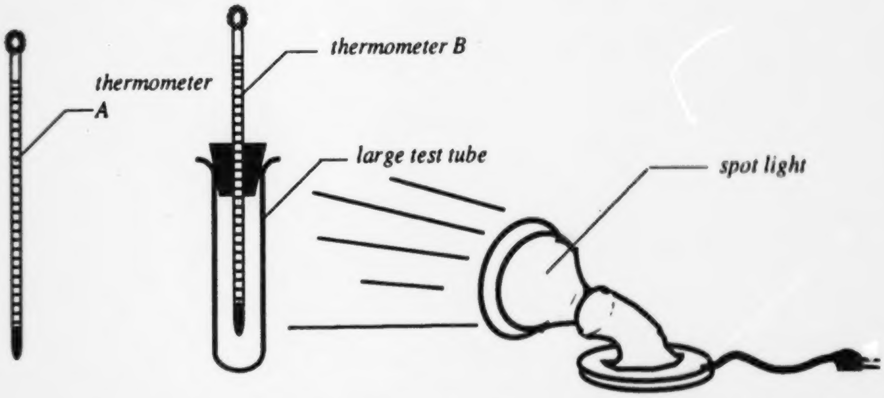
The sunshine is hottest around noon time, because at that time the sun rays fall on the earth almost perpendicular to the surface of the earth. Early in the morning or late afternoon the sun is closer to the horizon, and the sun rays strike the earth surface in an angle. This makes the number of rays per square area much less, and thus the intensity of the sun is not as severe.



2.1.10. THE TEST TUBE GREENHOUSE

Materials: 1. Two thermometers (0-100°C). 2. A large, wide test tube or long jar with a narrow mouth. 3. One-hole stopper to fit the thermometer in the test tube. 4. A white or infra red spot light.

Procedure:



1. Insert one thermometer in the one-hole stopper and place this over the large test tube or jar (if a loose thermometer is not available, a paper covered jar may be used instead of the large test tube and the stopper).
2. Place both thermometers in the sunlight or shine the spot light on them from about 50 cm away (see Sketch above).
3. Have the students read and record the temperatures of both thermometers every minute for about 15 minutes.

Questions:

1. Which of the thermometers shows a higher temperature?
2. What is the light heating around thermometer A, and what is it heating around thermometer B? (see Sketch above)
3. What do these results tell us when applied to a sun room or greenhouse?
4. Which direction should these sun rooms face when your home is located in the Northern hemisphere? In the Southern hemisphere?
5. Would the temperature on thermometer B be higher or lower if the tube or jar were made of opaque glass? If the tube or jar were covered with white paper? If it were covered with black paper?

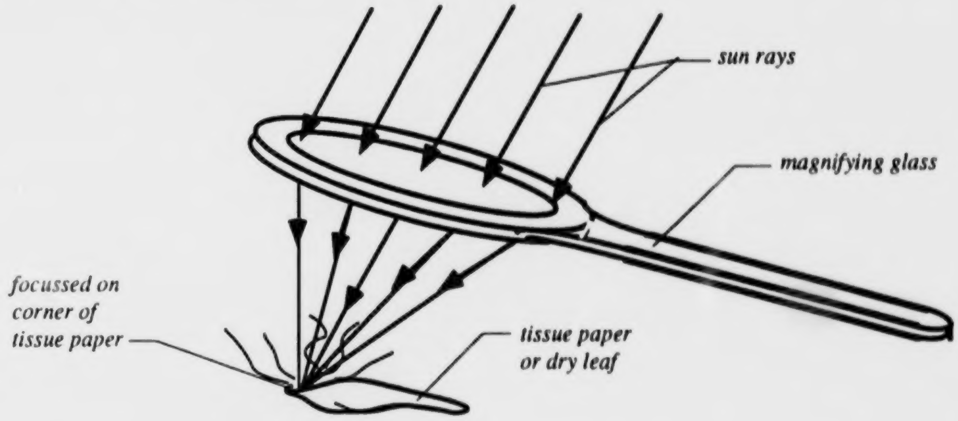
Explanation:

Like the atmosphere of the earth, glass around the thermometer can trap heat energy. The light rays heat up the air in the tube, which cannot move around, contrary to the air around thermometer A. Similarly, sunlight energy is trapped in the atmosphere, as the sun's energy is absorbed by the earth. Part of this energy is reradiated into the atmosphere but cannot pass out of the atmosphere.

A **greenhouse** works on the same principle. If the glass walls of a greenhouse were covered with black material, it would make the room much hotter, but since plants need light, glass is needed. Other examples of energy traps are: closed cars left in the sun, especially the dark colored ones; attics of homes with black roofs, etc.

2.1.11. START A FIRE WTTH A MAGNIFYING GLASS

Materials: 1. A large magnifying glass (or strong reading glasses).
2. A bright sunny day, over-exposed film or dark glasses.
3. A piece of tissue paper (or any easily combustible material).



Procedure:

1. Take the class outdoors on a bright sunny day, and bring the large magnifying glass or a pair of strong reading glasses with you. You also should have a piece of tissue paper or any thin paper in your pocket.
2. Place the tissue paper on a spot where everybody can see it. Let the students use the darkened film or dark glasses to observe the paper, while you hold the magnifying glass about 20-30 cm above the paper. This distance has to be varied by moving the lens up or down, such that the sun rays are focussed on the paper. (The small bright circle has to become a small point if it is well focussed).
3. Hold the magnifying glass at that position (focussed position) for awhile (about 15-20 sec) until suddenly the paper starts to smolder and burn.

Questions:

1. What made the paper burn?
2. Why would the paper not burn without the magnifying glass?
3. What would it depend on how high we have to hold the lens to focus it?
4. What else beside thin paper can we use to burn?
5. How are forest fires sometimes started by nature?
6. What did the magnifying glass actually do with the sun rays?

Explanation:

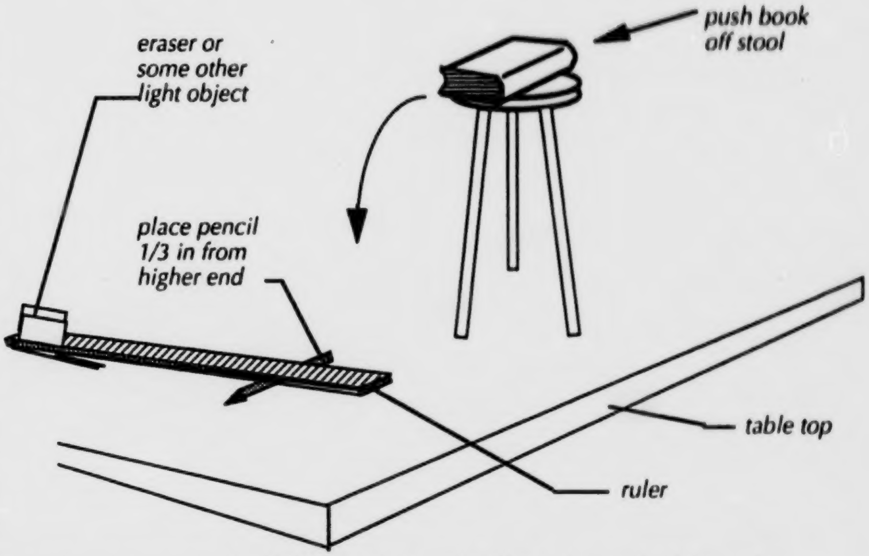
What the magnifying glass or lens does, is concentrating all the sun rays that were falling on it, into one point. This increased the intensity of the heat 100 or may be 200 fold, depending on how large and how strong the lens is. You will find that on clear sunny days it is much easier to start the fire, than it is on hazy or cloudy days. The stronger the lens (more convex) the closer we have to hold the lens to the piece of paper to focus the sun rays.

Dry leaves can easily be substituted for the tissue paper. In nature, forest fires are sometimes caused by concentrated sun rays. Lingering dew drops between plant leaves can act as lenses and the concentrated sun rays may fall on very dry leaves, and a forest fire is in the making!

2.1.12. DOES A BOOK HAVE ENERGY ?

What you need: 1. A heavy book (encyclopedia or dictionary).
2. A meter stick, pencil and eraser. 3. A high stool.

How to set it up:


eraser or some other light object
place pencil 1/3 in from higher end
push book off stool
table top
ruler

1. Place a stool on the table top and put a heavy book on the stool. Ask students: "Does the book have any energy at this position?"
2. Place the meter stick on the table top about 20-30 cm in front of the stool, such that when the book is pushed off the stool, it will fall on the end of the ruler.
3. Insert a thick pencil under the meter stick, about one-third from the end where the book will be falling on.
4. Place an eraser on the other end of the meter stick.
5. Push the book off the stool (and let it fall on the meter stick). Watch the eraser fly up!

What questions to ask:

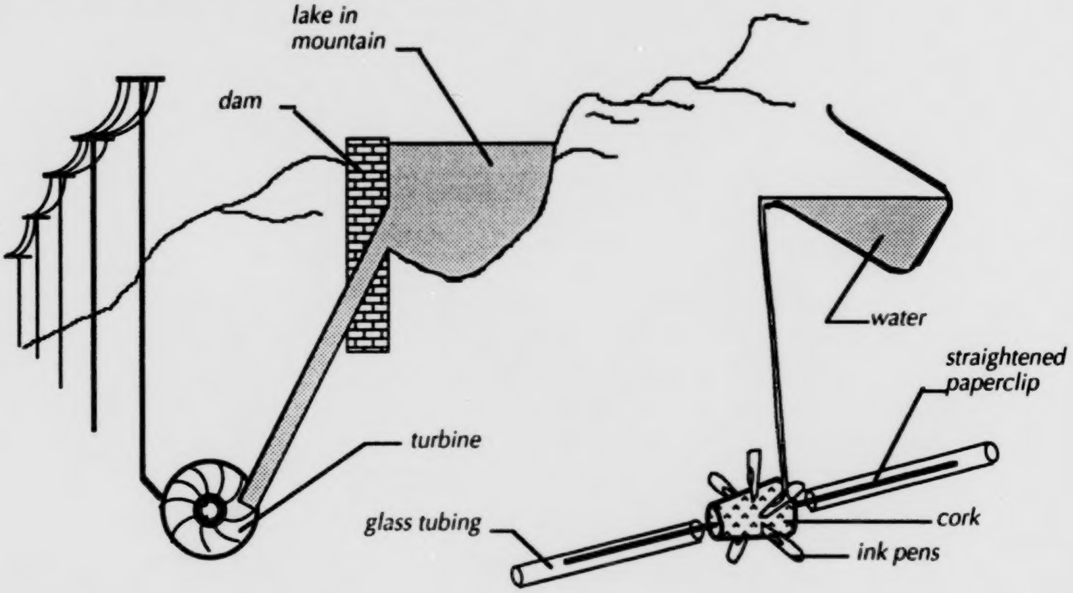
1. What kind of energy did the book have when it was lying on the stool? When it was falling on the ruler?
2. Does the book have any energy lying on the table top?
3. What type of energy did the book impart on the meter stick?
4. What kind of energy did the eraser obtain?
5. What was the original source of energy that triggered the flying eraser?

How to explain it:

When the book was lying on top of the stool, it had **potential energy**. As long as the book has the potential of falling towards the center of the earth, it has potential energy. Thus when it was lying on the table top after falling off the stool, it still possesses potential energy (to fall off the table and send another eraser flying). At the moment that the book was falling, this potential energy was transformed into **kinetic energy**, which was turned into **mechanical energy** of the moving meter stick, and this was imparted to the eraser, which obtained kinetic energy. The original source of energy of this whole chain reaction was human muscle energy, which can be traced back to **solar energy**.

2.1.13. DOES WATER IN A LAKE HAVE ENERGY ?

What you need: 1. A large beaker, two short glass tubes. 2. A cork, 6 old ink pens, 2 paper clips. 3. Two clamps and two stands, if available.



How to set it up:

1. Push the six ink pens radially in the cork and set the materials up like in the sketch, so that the cork can rotate freely.
2. Hold the water-filled beaker above the cork and tell students: "This represents water in a lake up in the mountains."
3. Ask the students: "Does the water have energy? What kind?" Pour the water on one side of the cork on the protruding pens (do this over a sink or a container to catch the water).

What questions to ask:

1. What kind of energy does the water in the beaker have?
2. What kind of energy was moving the cork?
3. What is the resultant type of energy produced?
4. If the water in the beaker can be compared to the water in a lake, what can we compare the rotating cork with?
5. What kind of energy do we need to bring the water up in the beaker?
6. What type of energy is needed to fill up a lake with water?

How to explain it:

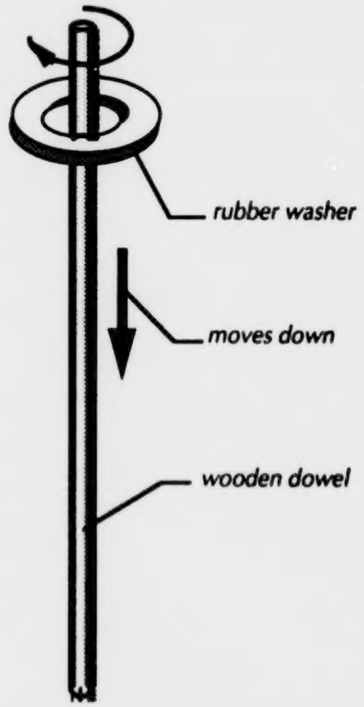
The water in the beaker, held up high, is comparable to the water in a lake up high in the mountains, possessing **potential energy**. The energy may be released and transformed into **kinetic energy** by building a dam and controlling the flow of the water. By letting the flow of water pass the turbines, represented by the cork and protruding ink pens. The kinetic energy of the water is transformed into **mechanical energy**, which in turn is transformed into **electrical energy**. This last step takes place in the generators, being rotated by the turbines.

2.1.14. THE SPINNING RINGS

What you need: 1. A 1 cm diameter wooden dowel (about 1 m long).
2. Large rubber washers (about 2-1/2 - 3 cm in diameter).

How to set it up:

1. Hold the dowel vertically on the table top and the rubber washer at the top of the dowel. Ask the students: "How long will it take for the ring to drop the length of the wooden dowel?" (Anticipated answer: 'A fraction of a second').
2. Give the ring a spin at the top of the dowel and time its fall. Ask: "Why is the fall not occurring in a uniform motion?" Observe the spinning and the falling speed carefully (when the falling slows down, the spinning or rotation of the washer increases).



What questions to ask:

1. How long did it take for the spinning ring to fall?
2. What made the ring keep on spinning?
3. What kind of energy did the ring at the top of the dowel have?
4. Why did the ring spin faster after a sudden drop in height?

How to explain it:

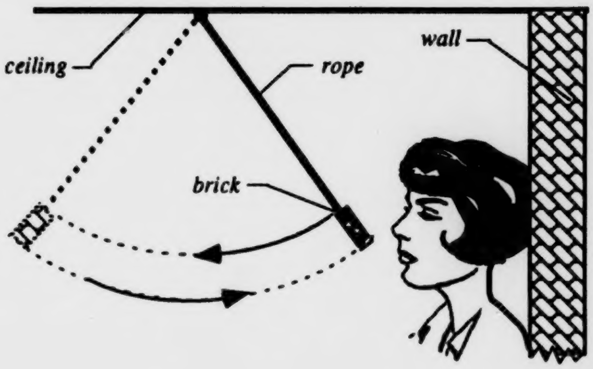
The friction between the dowel and the ring prevents the ring from dropping straight down. The faster the ring is spinning, the larger the force perpendicular to the dowel, and thus the stabler its **plane of rotation**. By dropping, **potential energy** is transferred into **rotational kinetic energy**. It can be shown that the rotation of the ring requires energy by spinning it on a horizontal dowel (one spin will probably spin it for a few seconds). The potential energy that the ring possessed at the top of the dowel is not completely transformed into the **rotational kinetic energy**, but some heat of friction has no doubt developed between the dowel and the ring.

We can observe that the ring sometimes drops much quicker at times and then slows down in the fall, but then the spinning suddenly increases in speed. This shows that indeed **potential energy** is transformed into **kinetic energy**, and this in turn is transformed again into rotational kinetic energy, which is the spinning of the washer.

2.1.15. WILL THE HEAVY BRICK HIT YOUR NOSE ?

Materials: 1. A heavy masonry brick or large bowling ball. 2. A strong nylon rope.

Procedure:



1. Tie the brick or bowling ball to one end of the rope and suspend the pendulum about 3 m from the wall to the ceiling.
2. Before securing the knot in the rope, adjust the length of the pendulum such that the highest swing just reaches your nose when you stand with your back against the wall (see Sketch on right).
3. Make sure that the knots are tight and secure and cannot slip.
4. Now bring the pendulum as close as possible to your nose and let go. **(CAUTION: DO NOT PUSH THE PENDULUM AWAY FROM YOU!) .**
5. Stay perfectly still against the wall and let the pendulum swing back. (Ask the students: "Who dares to do this?")

Questions:

1. Why is it perfectly safe to stand against the wall and not get hit?
2. Will the pendulum ever swing higher than its first position?
3. What would give the brick a higher swing?
4. What forms of energy are involved in a swinging pendulum?
5. Where does the energy go? What does it turn into?
6. In which positions of the swing does the pendulum have the greatest kinetic energy? The greatest potential energy?
7. What would happen if the brick was swung in a vacuum?
8. What makes a clock pendulum swing? When does it stop?

Explanation:

When the brick pendulum is released for the first time, it loses some of its energy due to friction at the suspension point and mostly in air resistance. This energy is turned into heat or actually faster moving rope and air molecules. This loss occurs with every swing of the brick and thus each swing becomes lower and lower **(amplitude gets smaller).** A higher swing would only be obtained if we add energy to the pendulum by giving it a push **(do not do this while you are still standing against the wall!).**

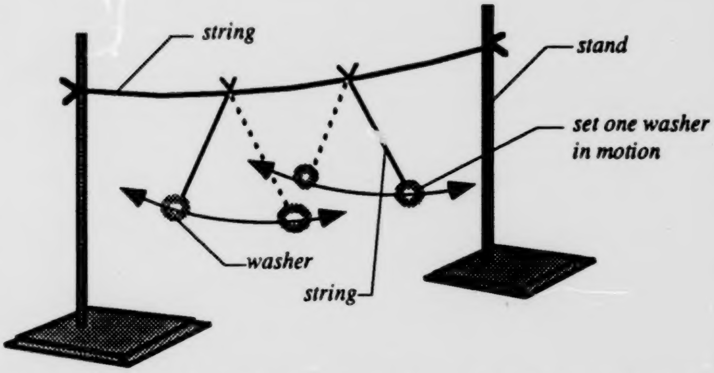
If this brick pendulum was swung in a vacuum, energy loss would only occur in the rope and the suspension point, and the swinging would last for a much longer time before it stops.

In a clock pendulum the swinging is kept going by the spring of the clock. A small amount of energy is added to each swing by the potential energy of the wound up spring. When the spring is completely unwound, the clock and the swing of its pendulum stops.

2.1.16. THE TWIN PENDULUM

Materials: 1. Two identical washers (or any other object to make a bob).
2. Thin string or strong thread.
3. Two vertical stands.

Procedure:



1. Place the two vertical stands about 30 cm apart from each other and tie a piece of string horizontally from one stand to the other.
2. Tie a short piece of string (about 15 cm) to each of the washers (or pendulum bobs) and tie the other end to the horizontal string, about 5 cm apart from each other - make sure that the bobs hang down from the horizontal string at the same height!
3. Let the two pendulums hang perfectly still: now you are ready for the demonstration. Ask: "What will happen to the second pendulum if I start swinging the first one?" Anticipated answer: "Nothing!"
4. Pull out the first pendulum carefully by the bob (hold the string tight) and let go of the bob: OBSERVE!

Questions:

1. What happened to the second pendulum?
2. Where did all the energy of the first pendulum go to?
3. What made the second pendulum pick up the energy?
4. Would a pendulum that was a little longer or shorter than the first one also be able to pick up the energy?
5. Would the second pendulum also pick up energy from the first if they were both tied to a solid metal rod instead of a string?
6. Did the first pendulum completely stop after the energy was transferred?
7. If compared to just one pendulum swinging from a similar support, which of the two systems would swing the longest? Which are the variables?

Explanation:

Only when the two pendulums are perfectly identical in length, will the **energy** of the first pendulum be **transferred** totally to the second. The first pendulum then stops and in turn picks up the energy from the second, etc. until the energy is dissipated into heat, and both pendulums stop swinging.

The energy from the first pendulum is transferred to the second only because of the flexible horizontal support, which moves in phase with the swing of the second pendulum. These movements keep on strengthening the swing just like the push that we give to a child on a real swing in the park.

A CONCEPT IN SCIENCE

IS SYNONYMOUS WITH
A CORRESPONDING

SET OF OPERATIONS

- Paul F. Brandwein

Firing "The Tin-can Bazooka", which
corresponds with the concept of:
Turning Chemical Energy into Kinetic Energy.

CHAPTER 2

HOW DOES HEAT AFFECT THINGS ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

— Heat travels by **conduction** in solids.
— Heat travels by **convection** in fluids : liquids and gases.
— Heat travels by **radiation** in fluids and in vacuum.
— Heat makes solids, liquids, and gases **expand**.
— Cooling makes solids, liquids, and gases **contract.**
— A substance does not burn unless its **kindling point** is surpassed.

CAUTION

Every single one of the events in this chapter has actually to have a **fire hazardous label** put on, as in each event heat is involved that has to come from a burning candle or a burning alcohol flame.

When using an **alcohol burner**, make sure the lid is screwed on tightly before lighting. Always have a large **empty tin can** (juice can) at hand that you can use to place upside down over a fire that could be caused by a knocked-over burner.

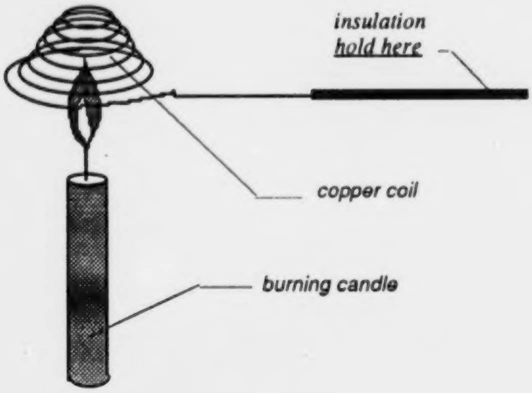
Always work together with an adult when using a flame or matches, or when working with flammable liquids, like alcohol.

Never use an alcohol burner near materials that easily can catch fire, like paper or a table cloth. Place it on a tile or dinner plate, never on a bare wooden table!

YOU CAN NEVER BE TOO CAREFUL !

2.2.01 THE COIL CANDLE -SNUFFER

What you need: 1. Insulated solid copper wire (about 30 cm).
2. A wire stripper or knife.
3. A birthday candle & matches.



How to set it up:

1. Take the copper wire and strip 3/4 of the insulation off one end (use the wire stripper or knife).
2. Make a spiralling coil of the stripped end of the copper wire.
3. Light the candle and fasten it to the table with a drop of molten wax.
4. Lower the coil over the candle flame quickly; the flame is snuffed!
5. Relight the candle; and now lower the coil slowly over the flame (hold it in the flame for a while), then lower the coil over the candle: **flame stays on!**

What questions to ask:

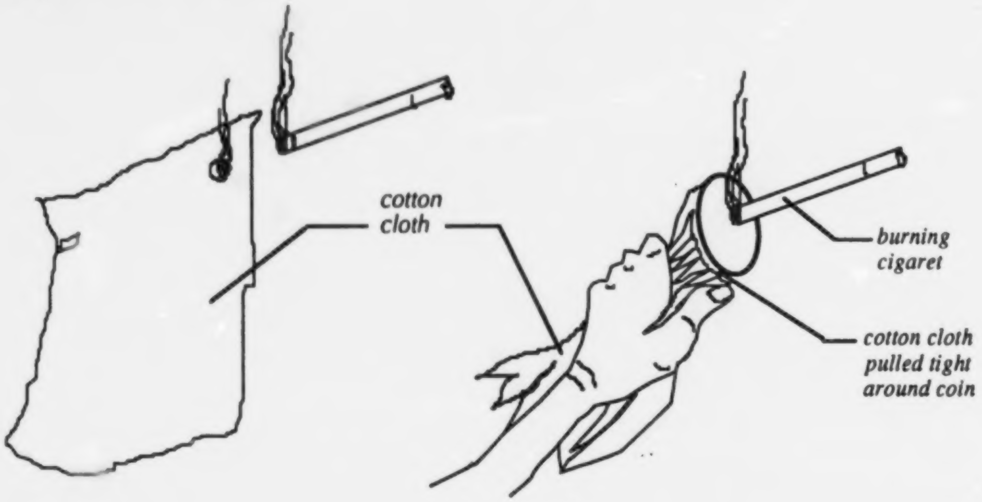
1. What made the flame go out when the coil was lowered quickly?
2. Was the flame cut off from the air?
3. Why did the flame stay on after the coil was held in the flame for a longer period?
4. What was the temperature of the coil the first time compared to the second time it was lowered over the flame?
5. Why was the insulation not completely stripped off from the wire?

How to explain it:

In lowering the copper spiral over the flame, it was conducting the heat away from the flame. This made the surrounding of the flame suddenly drop in temperature, which made the flame go out. In other words, the temperature dropped below the **kindling temperature** of the candle wax. When holding the coil for a longer period of time in the flame, it is heated to a higher temperature. When this hot coil is now lowered over the flame, it will not extinguish it, because the surroundings of the flame have a temperature which is higher than the **kindling point** of candle wax. The insulation of the wire was left on at one end of the wire in order to prevent conduction of the heat to the fingers. Without insulation it would be too hot to hold the coil with the bare fingers.

2.2.02. THE CHARLESS COTTON

What you need: 1. A quarter coin or any large coin (copper is best).
2. A piece of old cotton cloth.
3. A cigarette and matches.


cotton cloth
burning cigaret
cotton cloth pulled tight around coin

How to set it up:

1. Take the piece of cotton cloth, light the cigarette and show students how easy it is to burn a hole through the cloth (in the corner of it).
2. Wrap the cotton cloth over the coin tightly and hold it in one hand.
3. With the other hand, push the lit cigarette against the cloth on the coin — cotton cannot be charred or burnt!
4. Take the cigarette off the cloth and show no charred spot on the cloth.

What questions to ask:

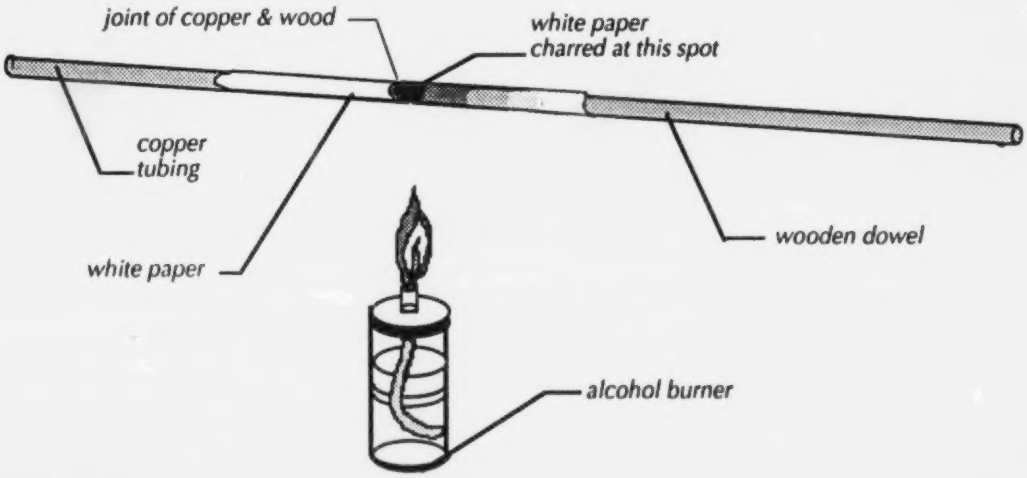
1. Why was it not possible to char the cotton on the coin?
2. Why is it so easy to burn a hole in the cotton without the coin?
3. After the attempt to char the cotton, how does the coin feel?
4. Could the quarter be replaced with a penny? A nickel? An iron disc? A wooden disc? A plastic disc?
5. What temperature does the cotton have to reach in order for it to burn?
6. What was the purpose of the coin?
7. How did the heat travel away from the cotton?

How to explain it:

The heat from the lit cigarette is enough to easily char or burn a hole in the cotton cloth. With the cloth drawn over a coin, however, this heat was **absorbed** by the coin and conducted away from the cloth. The heat of the burning cigarette disappeared into the coin, lowering the temperature of the cloth, with the result that the cloth could not be charred. The cloth has to be held very tight over the coin in order for this demonstration to succeed. The closer the contact between cloth and coin, the better the **conduction** of the heat away from the cloth.

2.2.03. THE SCORCHING PAPER

What you need: 1. A short wooden dowel (about 10 cm).
2. A piece of copper rod or tubing (with the same diameter as the wooden dowel).
3. Paper, cellotape, alcohol burner/stove top.



How to set it up:

1. Take the wooden dowel and the copper rod (or tubing) of the same diameter, and join them together by wrapping one layer of white paper around them (use cellotape only at the end of the paper — make sure that the paper is tight against the rods).
2. Hold the metal rod and heat the piece of paper evenly over the colorless flame of the alcohol burner/or over the stove top, by moving it back and forth above it (do not let the paper touch the flame). Continue this heating until some scorching of the paper occurs.

What questions to ask:

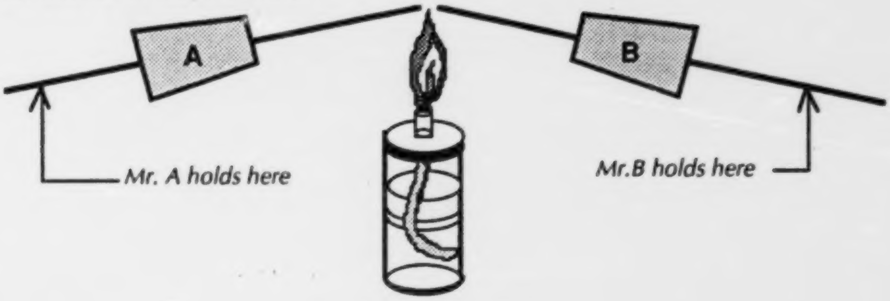
1. Where did the scorching occur?
2. Why did the paper only scorch on one side?
3. Could a candle flame replace the alcohol burner?
4. Why do we need to heat the paper evenly?
5. What would happen to the paper if the copper rod were replaced by a piece of rubber tubing? Glass tubing?
6. What would the paper do if we had more than one layer of paper wrapped around the rods?

How to explain it:

The copper tubing, compared to the wooden dowel, is a much better heat **conductor**. The heat on the copper side was therefore **conducted away** from the joint which was heated, whereas the heat on the wood side stayed where it was. The temperature at the wood side got much higher than that at the copper side, thus scorching occurred on the wood side. When the metal rod is replaced with less good conductors of heat, like rubber or glass, the scorching will most likely occur on both sides of the paper , as the heat build-up will take place on both sides.

2.2.04. THE HEAT RACE (I)

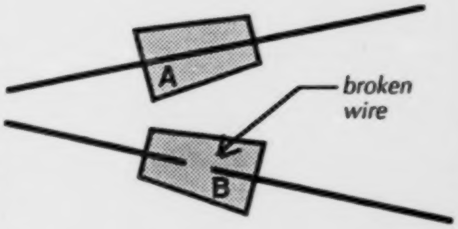
What you need: 1. Two small corks.
2. One long and 2 short pieces of copper wire.
3. An alcohol burner or large candle.



How to set it up:
1. Cut the following lengths of copper wire: 10 cm, two 4-1/2 cm.
2. Push the 10 cm wire through one of the small corks (see Cork A).
3. Push the two short wires through each end of the other cork (Cork B).
4. Let two students (or yourself and a student) hold one end of the wire and keep the other end in the alcohol burner flame. (Do not reveal to the students that the wire in cork B is broken—soon Mr. A (the one holding cork A) will let go of the wire!).

What questions to ask:
1. Why did Mr. A have to let go of the wire?
2. Why can Mr. B keep on holding the wire in cork B?
3. What can you infer about the wire in cork B?
4. By what means was the heat transferred to Mr. A's fingers?
5. What would Mr. A have to do in order to be able to further heat wire A?

How to explain it:

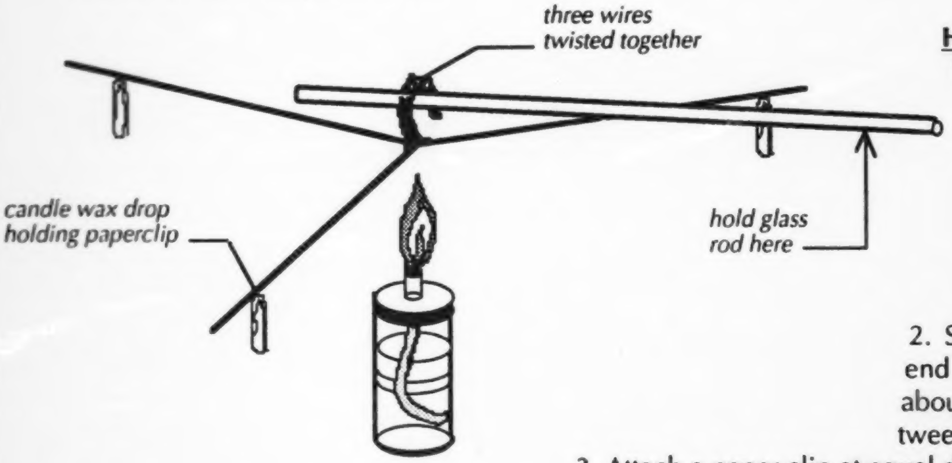


Mr. A had to let go of the wire containing cork A, because the heat from the alcohol flame was **conducted** to the end where the wire was held. This end eventually became too hot to hold. The students could infer about the wire in cork B, that it was made of poor-conducting metal or some other **non-conductive** material, or that it was broken in the cork and thus not further conduct the heat to the fingers.

In order for Mr. A to keep on holding the wire with cork A, he has to put some **non-conductor** of heat between the wire and his fingers. This will stop the heat conduction to his fingers and he will be able to keep holding the wire. In Mr. B's case the heat conduction was stopped in the cork, because the wire was broken in cork B.

2.2.05. THE HEAT RACE (II)

What you need: 1. A glass rod or tube (about 20 cm long).
2. A copper, iron, and aluminum wire (15 cm each).
3. An alcohol burner.
4. A candle and three paper clips.


three wires twisted together
candle wax drop holding paperclip
hold glass rod here

How to set it up:

1. Take equal lengths (15 cm) of a copper, iron, and aluminum wire and twist them together at one end.
2. Spread the other end wide out with about 120° angle between them.
3. Attach a paper clip at equal distances (10 cm) from the twisted end with a drop of melted wax (from the candle).
4. Bend the twisted end so it can hang over the glass rod.
5. Heat the twisted end over the alcohol flame and measure the time it takes for the paper clips to drop.

What questions to ask:

1. Which of the paper clips dropped first, second, and last?
2. Which of the metals is the best heat conductor? Which the worst?
3. Which variables do we have to keep constant for this race?
4. Which are the manipulated and responding variables?
5. Would more or less wax holding the clip have any influence in the race?

How to explain it

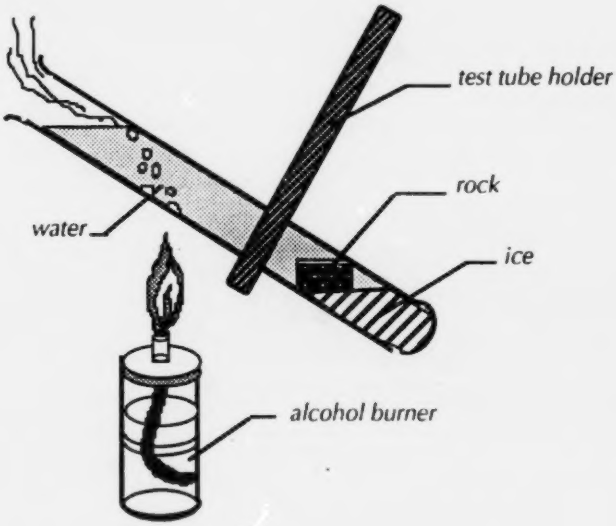
Although the paper clips are attached at the same distances from the twisted end and thus from the alcohol flame, they do not fall off at the same time. This is because the **thermal conductivity** of each of the metals is different. Copper has the highest thermal conductivity, then comes aluminum, and last is iron; meaning that copper can conduct heat the easiest. The variables that are influencing the race are: the position of the flame, the amount of wax used to attach the paper clip, the dimensions of the wire, the distance of the paper clip from the flame, the size of the paper clip, and many more, which have to be held constant for this race. The **manipulated variable** is the kind of metal (this is different in the three wires) and the **responding variable** is the time the clip could hang on to the wire after heating was started, or the thermal conductivity of the metal. The heat is **conducted** from the twisted end towards the open end in each wire. The heat melts the drop of wax to which the paper clip is attached, and this latter falls off.

2.2.06. CAN ICE -WATER BOIL?

What you need: 1. Small ice cubes (crushed ice).
2. A wide test tube and holder.
3. A small weight or rock.
4. An alcohol or Bunsen burner.

How to set it up:

1. Place some ice cubes in the test tube (about 1/3 full) and put a rock or small weight on it in the tube.
2. Pour water in the tube until almost full.
3. Clamp the test tube in the tube holder and hold the upper part of the test tube in the flame of the alcohol or Bunsen burner (see Sketch), until the water boils.
4. Show students that the ice cubes are still present beside the boiling water in the top of the tube.



What questions to ask:

1. Why did the ice not melt by the heating?
2. What is the purpose of the rock?
3. Would this demonstration work without the rock?
4. Was the water conducting the heat well?
5. Were there convection currents taking place in the test tube?

How to explain it:

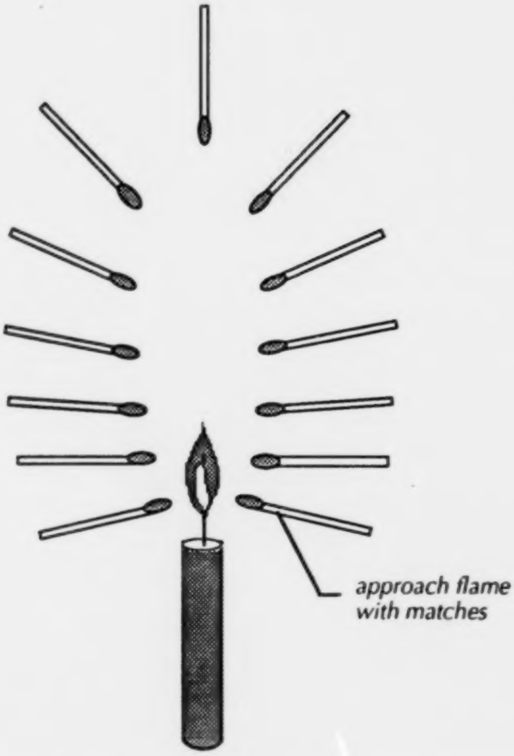
The ice is kept in the lower part of the test tube by the rock or small weight. Without the weight, the ice would float in the test tube and heating this would melt the ice first before the water can boil. By keeping the ice down in the test tube, the water in the upper part can be heated and boiled without melting the ice, because hot water is lighter than cold water. Very little convection takes place: only in the upper part of the test tube. Another reason for the ice not melting is, that water is a **poor conductor** of heat. The heat from the upper part of the test tube is therefore not conducted to the ice in the lower part of the tube.

2.2.07. THE CONVECTION TESTER

What you need: 1. Candles (for each pair of students - if teaching a class).
2. Matches

How to set it up:

1. Distribute a candle and a book of matches to each pair of students in the class, and instruct them to do the following points.
2. Light the candle and secure it to the desk.
3. Approach the candle flame with the match head from different angles until it bursts into flame (make sure that the flame is straight up).
4. Estimate (or measure) and record the nearest distance between the unlit match and the flame at the different locations (see Sketch).



What questions to ask:

1. Why can we approach the flame closer at the bottom of the flame?
2. What does the air do above the flame?
3. Why can't we come closer to the flame if we approach it with the match head from above without burning it?
4. What temperature is exceeded when the match head bursts into flame?
5. Do the match heads burst into flame at exactly the same temperature?
6. What are the variables influencing the ignition of the match heads?
7. Would a propane or Bunsen burner flame behave in the same manner?

How to explain it:

The heat from the flame creates a convection in the air, making the spot above the flame have a higher temperature than anywhere else around the flame. The reason for this is that hot air is lighter than cool air. As the spot above the flame is hotter, the match heads can approach the flame at the bottom of it much closer than at the top of the candle flame before bursting into flame. The heat reaching the match heads at the lower part of the candle flame is mostly **by radiation** and not **convection** of heat.

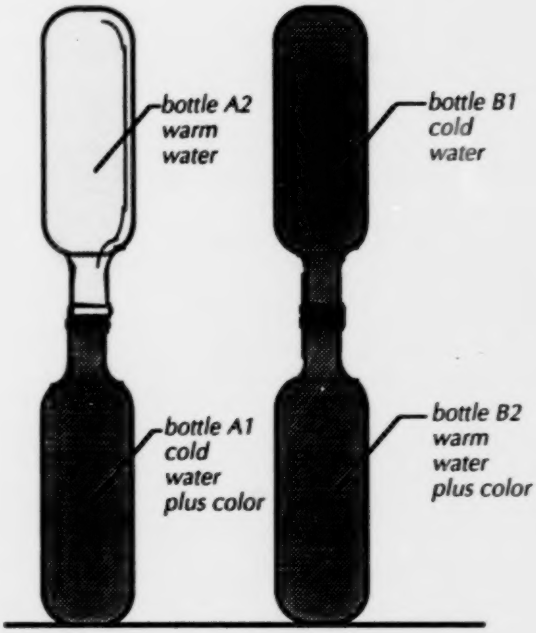
This demonstration or activity has to be carried out in a draft-free room, to that the hot air will rise straight up. If high-temperature thermometers are available, the thermometers can be used in place of the matches to measure the temperature at the different spots.

2.2.08. THE CONFUSED BOTTLES

What you need: 1. Four empty identical soda pop bottles.
2. Food coloring. 3. A 3x5" card.

How to set it up:

1. Fill two bottles (A1 and B1) with cold and two bottles (A2 and B2) with warm water (do not reveal to students the temperature difference).
2. Color the water in bottles A1 and B2 with a few drops of food coloring and mix the color evenly (cover the bottle with your thumb and turn upside down).
3. Cover the bottles A2 and B1 with a small piece of the paper card, and place them upside down on the colored bottles (one finger on the card will keep the water from spilling while turning it upside down: center the bottles A2 and B1 carefully over A1 and B2 and slip out the piece of card by holding the top bottle).
4. Let the students observe what is happening to the color



What questions to ask:

1. Why did the top bottle B get colored and not Bottle A?
2. Do you think the temperature of all four bottles of water was the same?
3. Which of the four bottles were warmer?
4. Does bottle A2 ever get colored; if so, when?
5. What would happen to the color if the temperature of all four bottles were the same?

How to explain it:

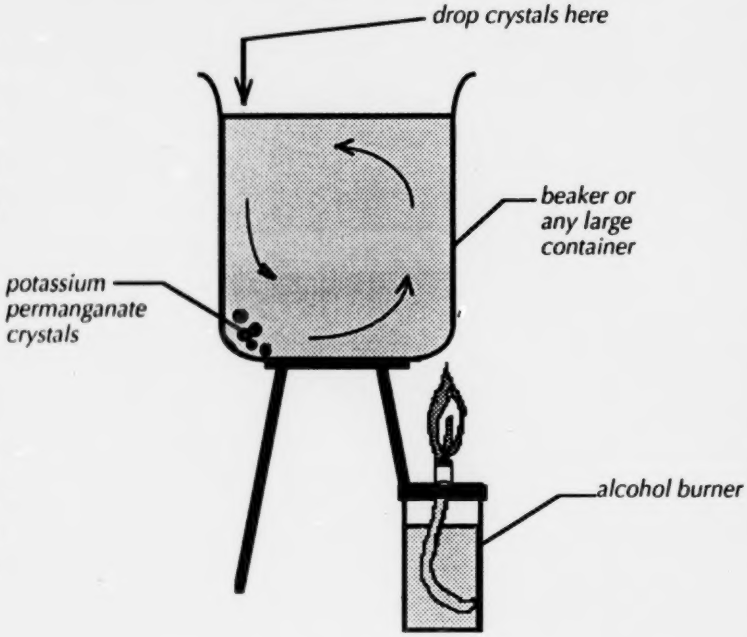
The water in bottles A1 and B1 was cold and that in A2 and B2 was warm. Warm water is lighter in weight or less dense than cold water and thus rises. Since the warm water in B2 was colored this water rises into the top bottle and the cold water sinks bringing with it **convection currents.** As the water in A2 is warm and already above the cold water in A1, no convection is occurring in this set of bottles, and thus no coloring of the top bottle. When the water temperature of this top bottle gets to be equal to that of the lower bottle, **diffusion** of the color will occur, but no **convection.** This process is much slower than convection and is caused by the constant vibration/movements of molecules.

2.2.09. INTERESTING CURRENTS

What you need: 1. A large beaker (800 - 1000 ml) or large glass container.
2. An alcohol or propane burner or large candle, and tripod.
3. Potassium permanganate ($KMnO_4$) or food coloring or ink.

How to set it up:

1. Fill the large beaker with water and place it on the stand (tripod)/set of books.
2. Light the alcohol or propane burner (or candle), but keep it away from the beaker.
3. Drop a few crystals of potassium permanganate ($KMnO_4$) or a few drops of food coloring close to one side of the beaker.
4. Quickly place the flame under the opposite side of the beaker, and let students observe the color movements in the water.


drop crystals here
beaker or any large container
potassium permanganate crystals
alcohol burner

What questions to ask:

1. What makes the $KMnO_4$ crystals sink to the bottom of the beaker?
2. What does the flame do to the water?
3. When the fluid expands, does it get lighter or heavier per unit volume?
4. When the fluid is heated, what characteristic is decreased?
5. Instead of using the flame, what could we use to achieve the same convection currents?
6. Where do we find these interesting currents in our daily life?

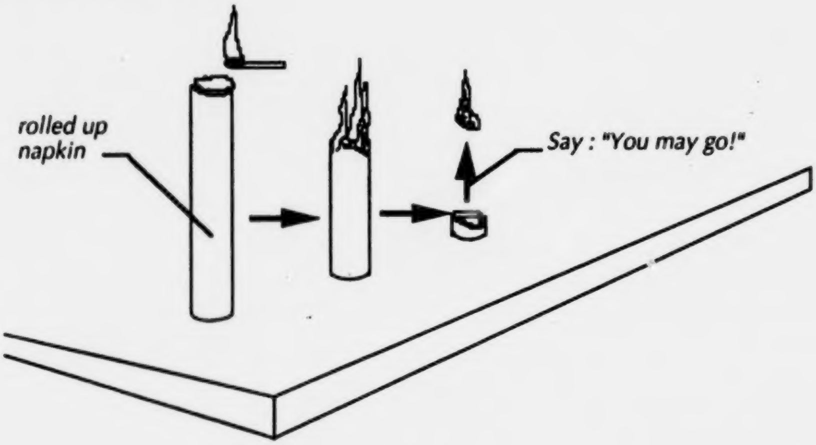
How to explain it:

The flame of the burner is heating the water on one side of the beaker, which makes the water expand at this spot, making the water less dense. As the density here decreases, the water gets lighter per unit volume and rises. The crystals of $KMnO_4$ are greater in density than water and thus they sink. As the hot water on one side of the beaker rises, the cold water on the opposite side of the beaker moves down, and a **convection current** is created in the water. This convection current is made visible by the color in the water, which is moved along with it.

In our daily life, warm currents can occur in oceans, like the Stream moving up north along the American Eastern Seaboard.

2.210. THE MYSTERIOUSLY RISING NAPKIN

What you need: 1. A thin paper napkin (the cheapest quality, rather crisp to the touch, used to replenish refillable dispensers).



How to set it up:

1. Test the napkin before the actual demonstration:
   a. Roll the napkin in a cylinder with about 3 cm diameter and let it stand upright on the table.
   b. Burn the napkin at the top and see whether the ashes stay together and lift off the table at the end of the burning.
   c. If the ashes stay together and it does not rise up towards the end of the burning, try it with 3/4 or 1/2 of the napkin, by tearing 1/4 or 1/2 of it off.
   d. Once the right kind of paper is found, you are ready for the actual demonstration.
2. Roll the napkin in a cylinder and let it stand on the table top.
3. Start to burn the napkin at the top of the cylinder. At this moment you may tell a story (about three guys who passed away and who were waiting to go into heaven at the Pearly Gate: St. Peter looking at the three stacked-up guys, was judging them for what they have done on earth; the first was not good enough, the second did not do enough good, but the third was OK and can go).
4. Just before the flame hits the table, say: "You may go!" (Or whatever comment suits your own story).

What questions to ask:

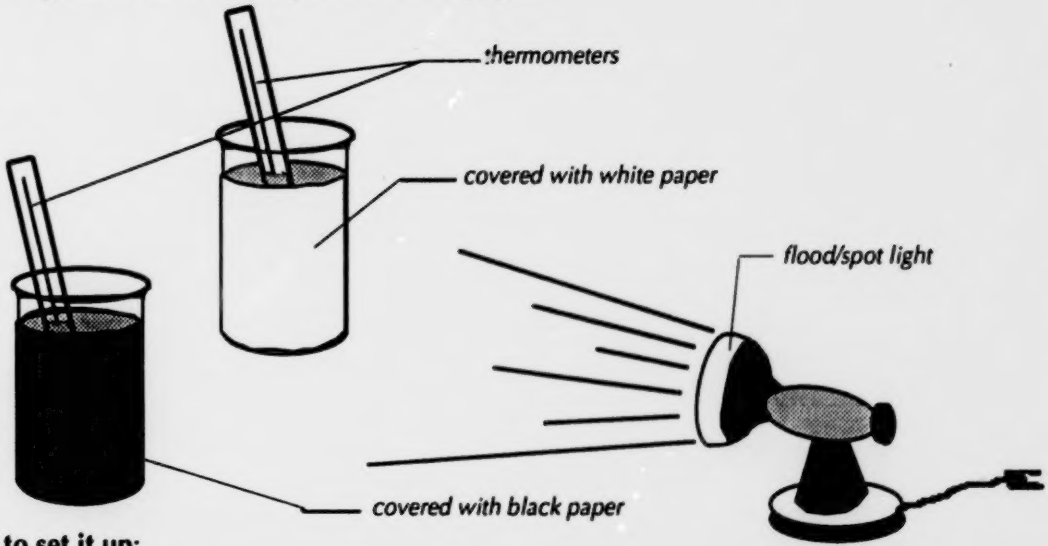
1. What made the ash shoot up in the air?
2. Why did the burning paper not rise up in the air before the flame reached the bottom?
3. Where can we see this phenomenon in our daily life?

How to explain it:

The ash content of the paper is critical in this demonstration. If the ash stays together and is light enough, it will reach the proper weight to be carried up by the **convection current** created by the flame.

2.2.11. WHICH IS THE WARMER COLOR ?

What you need: 1. Two identical beakers (100 ml) or drinking glasses.
2. Two identical thermometers. 3. A flood light or spot light.
4. A piece of white and a piece of black paper.



How to set it up:

1. Wrap 1 of the beakers with white and the other with black paper on the outside (tight against the glass with tape).
2. Fill both beakers with the same amount of water and immerse a thermometer in each and read off the temperature.
3. Place both beakers at the same distance (about 50 cm) from the spot light and switch the light on. (Or place them in sunlight).
4. Read the temperature of each beaker after a 5 minute exposure to the light or radiated heat.

What questions to ask:

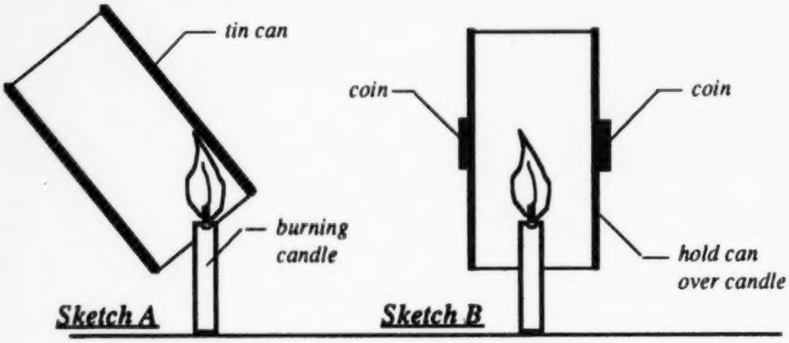
1. Which thermometer is indicating a higher temperature?
2. Why would the two beakers show different temperatures?
3. Which are the warmer colors in general?
4. What happens to the radiated energy hitting warm colored surfaces? And cold colored surfaces?

How to explain it:

The black surface **absorbs** the radiated heat much more than the white surface, which reflects all colors back. The black color is actually the absence of all other colors, and thus no emission of any other color occurs. The white color emits or reflects back all colors and thus does not absorb the **radiated** heat on the surface. In terms of molecules then, we can visualize that the molecules of the black surface vibrate much stronger than those of the white surface. The **radiated energy** is therefore imparted much easier to the water by the black surface than by the white one. The warmer colors are red, orange, brown, and yellow in contrast to the cold colors of green, blue, purple, violet. An experiment could be set up to test the absorption of radiated heat on these colored surfaces.

2.2.12. WHICH COIN WILL STAY ON LONGER ?

What you need: I. An empty juice can (or any other large tin can) of which the top and bottom has been taken off (remove with can opener). 2. A medium size candle, two identical coins.



How to do it:

1. Light the candle and blacken one half of the inside of the can with soot from the candle, by holding it sideways close to the candle flame (see Sketch A). Once this is done, let stand and cool at room temperature.
2. Against the outside of the tin can, attach one coin on each side of the can (the blank side and the soot-blackened side) with one drop of molten wax from the candle.
3. Now place the tin can (with the two coins attached) over the burning candle, and ask the students: "Which of the two coins will stay sticking to the can longer?" - Make sure that you place the can such that the candle is exactly in the center of the can. (See Sketch B).

What questions to ask:

1. What is the cause of one coin dropping first?
2. Which of the coins dropped first?
3. Will the other coin also drop off eventually or not?
4. Would blackening the outside of the can have the same effect?
5. How did the heat travel from the flame to the can?

How to explain it:

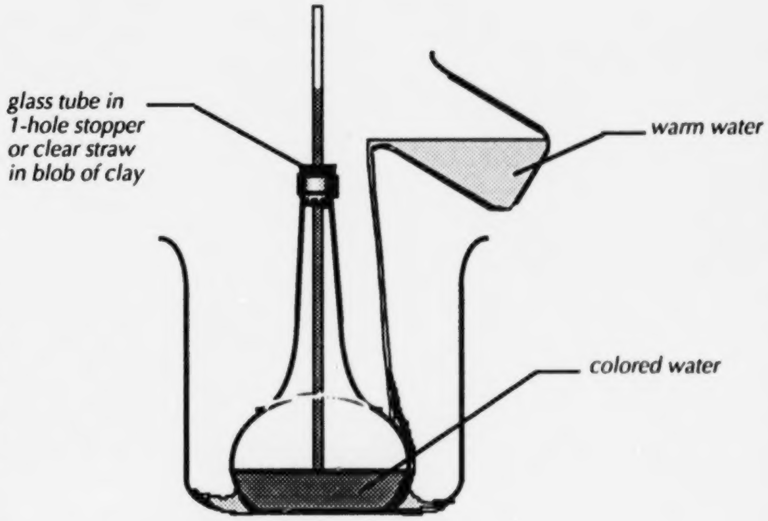
The coin attached to the side of the tin can that was blackened with the candle soot would fall off first. This is because the heat that was **radiated** from the candle flame was **absorbed** more by the black surface, as compared to the shiny metallic surface. Because of the higher degree of absorption of heat by the black half, the temperature increased more rapidly and thus the wax melted sooner and the coin would drop off before the other one.

If the outside of the can was blackened with soot instead of the inside surface, there would be no difference in the absorption of heat from the candle flame, as the inside surface would reflect the heat rays away in the same fashion. Absorption of heat from outside the can might then have an influence on making the difference in temperature, and thus in the length of adherence of the coins to the tin can.

2.2.13. THE RISING JUICES

What you need: 1. A flask or bottle with a narrow neck.

2. A glass tube (30 cm) in a 1-hole stopper (for flask) or clear straw and clay.
3. One large and one small container for water.
4. Food coloring or ink.



How to set it up:

1. Fill the flask or bottle 1/4 full with water and put a few drops of food coloring in the water.
2. Insert the one-hole stopper with the glass tube in the flask opening such that the lower end is immersed in the water or put a blob of clay around the clear straw and put the lower end in the water.
3. Push on the stopper or on the clay: the water level should rise in the tube.
4. Place the closed off flask in the larger container.
5. Pour some warm water from the smaller container over the flask: observe the water level inside the glass tube!

What questions to ask:

1. What made the water level in the tube rise?
2. When the pouring is stopped, what made the water level in the tube go down? Where will the water level stop?
3. Was the water that was poured on the flask cold or warm?
4. How different will the rising and falling of the water level be, if we poured oil instead of water on the flask?

How to explain it:

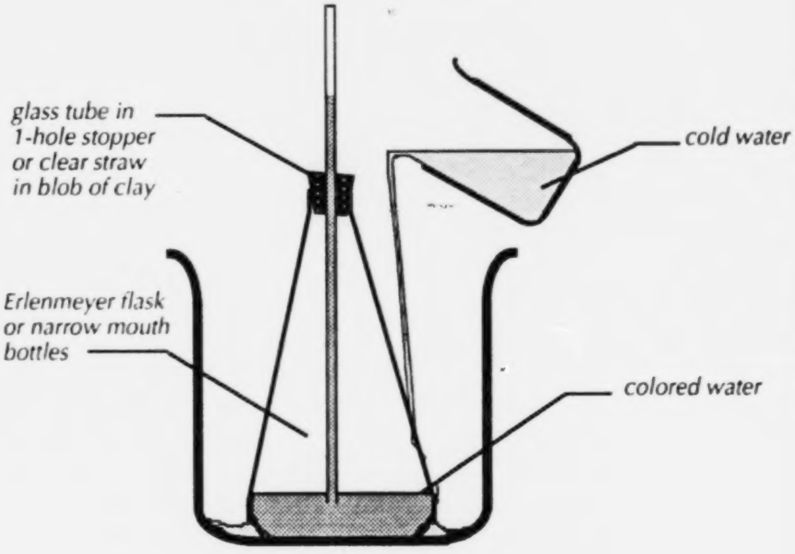
The water poured on the flask was warm, and this caused the air inside the flask to **expand**, pushing the water up in the tube. The higher the temperature of the poured water, the more the air inside the flask will expand and the higher the water inside the small tube is pushed up. When the pouring is discontinued, the water outside the flask is evaporating and cooling. This cooling makes the air inside the flask **contract** and the water column descends. If we use cold water instead of warm water to pour over the flask, the air inside it will also contract and bring down the water level in the tube. When using oil instead of water of the same temperature to pour over the flask, the rising of the water level inside the tube will be the same, but the falling will most likely be at a slower rate, because oil does not evaporate as quickly as water, and is thus not cooling as much.

2.2.14. WITHDRAWING JUICES

What you need: 1. An Erlenmeyer flask (250 ml) or any narrow-mouthed bottle.
2. A glass tube in a one-hole stopper (fitting in flask) or clear straw with clay.
3. A large transparent container, small beaker.
4. Food coloring.

How to set it up:

1. Fill the Erlenmeyer flask 1/4 full with colored water.
2. Insert the tube with the one-hole stopper over the flask (make sure that the tube dips in the water before pushing down on the stopper—the water level in the tube should stand higher than in the flask) or clay can be wrapped around the straw and pushed in the bottle.


glass tube in 1-hole stopper or clear straw in blob of clay
cold water
Erlenmeyer flask or narrow mouth bottles
colored water

3. Pour cold colorless water over the Erlenmeyer flask and have the students observe the water level in the tube.

What questions to ask:

1. Why did the water level in the tube go down?
2. Why did the water level in the tube rise again after the pouring was discontinued?
3. Was the poured water of the same temperature as the water inside?
4. What would happen to the water inside the tube if we would blow on the wet flask?
5. How can we make the water level in the tube rise in the first place?

How to explain it:

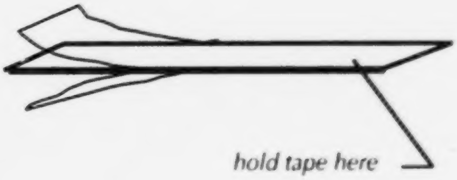
The cold water that was poured over the Erlenmeyer flask made the air inside the flask **contract**, thus the pressure on the water inside the flask was lowered. This made the water column inside the tube go down. When the pouring of the cold water is discontinued, the cooling action is not completely stopped because the flask is still wet, and evaporation of the water takes place. Not until the flask is completely dry, will the water column inside the tube rise again. By blowing on the wet flask, the cooling action—by evaporation of the water—is even more increased and a quick descent of the water results. The water level in the tube can be raised by pouring warm water over the flask or simply by holding the flask in both hands. Heating the flask over a flame will have the same results.

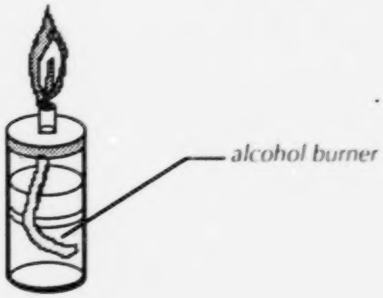
2.2.15. THE CURVING TAPE

What you need: 1. Masking tape and cellotape.
2. An alcohol burner or other burner with colorless flame/or stove top.

How to set it up:

1. Take a 10 cm piece of masking tape and an equal length of cellotape.
2. Stick the two pieces of tape with their sticky side together, such that one covers the other completely (cut any excess off).
3. Hold one end of the double tape above the alcohol flame (or the heat) and let students observe what happens with the tape.
4. Take the tape away from the heat, straighten it out, flip it upside down (conceal this from students) and bring it back over the flame: which way does the tape bend now?





What questions to ask:

1. Why did the tape curve up or down when heated?
2. Would a regular piece of masking tape behave the same way?
3. What would two pieces of masking tape stuck together do over the flame?
4. Which of the two tapes, masking or cello, expands more when heated?

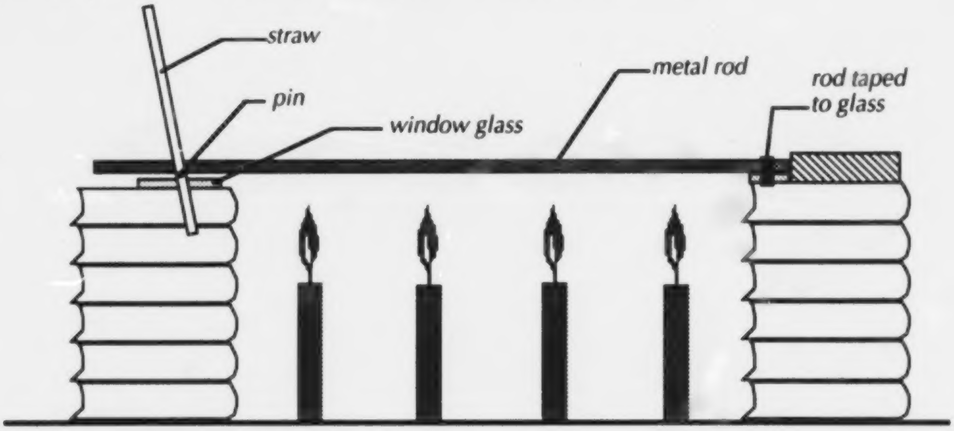
How to explain it:

A regular strip (single or double) of masking tape would not curve up or down when held above the flame. The curving occurs, because the cellotape **expands more** than the masking tape, and because one cannot slide past the other, it makes the double tape bend towards the masking tape .

This same principle is in operation in the **bimetallic strip**, which is a strip of two different metals with different **expansion coefficients** (they expand at different rates). These bimetallic strips are used for thermal switches, thermostats, on-off lights, etc. When the temperature reaches a certain point, the strip bends enough to switch the current off; when it gets cooler, the strip bends back and switches the current on again.

2.2.16. THE MOVING ROD

What you need: 1. A metal rod (about 50 cm long). 2. Two small pieces of window glass. 3. A straw and pin. 4. Four or five candles or alcohol burners.



How to set it up

1. Place the metal rod on the two small pieces of window glass on two stacks of books, so that it lies horizontally (see Sketch).
2. Tape one end of the rod against the glass and place a heavy book against the end of the rod.
3. Push a pin through a straw and place the pin between the other end of the rod and the glass piece, such that it can rotate freely.
4. Place four or five candle flames or alcohol flames under the rod.
5. Let students observe the straw.

What questions to ask:

1. How long after the candles were lit did the straw move?
2. In which direction did the straw move?
3. What was the cause for the straw to move?
4. Would the straw move the same way if the heavy book was removed before the heating of the rod?
5. What function do the glass pieces have?
6. What difference would we see in the movement of the straw, if we were to use more candles to heat the rod?
7. How would a change in the length of the rod affect the straw movement?

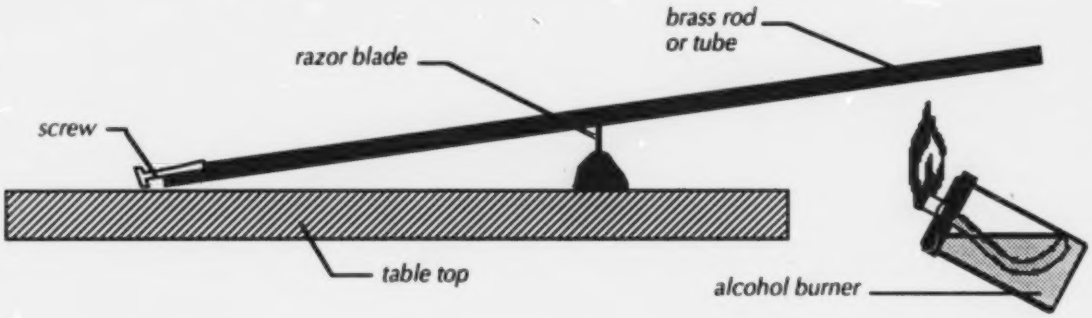
How to explain it:

The pin is tight in the straw and thus when the rod is heated, it **expands** and turns the pin. This is magnified by the movement of the straw. The straw does not move immediately after the candles are lit, but probably a few minutes afterwards. This is because the rod needs to absorb the heat and impart this energy to its molecules.

The two glass pieces under the rod function as an insulator of heat, as well as provide a smooth surface for the pin to roll evenly. The heavy book at one end of the rod keeps this end from sliding. More candles will heat the rod to a higher temperature and thus expand it more. The longer the rod the larger the increase in length.

2.2.17. THE HEAVY HEAT

What you need: 1. A brass rod or tube with screw in one end.
2. A razor blade, or small wooden block or molding clay.
3. An alcohol burner/candle.



How to set it up:

1. Turn the screw into the brass rod or tube about half way.
2. Stand the razor blade vertically in the block of wood or clump of clay (this functions as the pivot for the balance).
3. Place the rod or tube on the pivot and balance it, by moving it more to the left or to the right.
4. Turn the screw out so that the rod goes off balance (towards the screw).
5. Heat the other end of the tube with the alcohol burner (see Sketch).

What questions to ask:

1. What made the rod go off balance before the heating?
2. What happened to the rod when it was heated?
3. What made the rod tip towards the heated end?
4. What happened to the rod after the heat was taken off (after the rod tipped towards the heated end)?

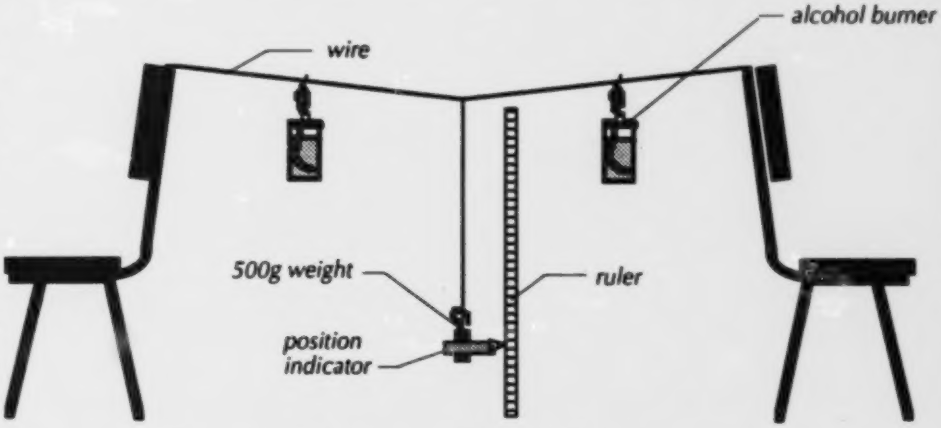
How to explain it:

Turning the screw out shifted the center of gravity of the rod a little towards the screw's end, causing the rod to tip over to the right, because there is more weight at that end. When the other end of the rod is heated, it **expands** and actually gets a tiny bit longer, causing the center of gravity to shift towards the heated side. As a result the rod is coming back to a level position. When the heating is continued, the rod would expand even more, and the rod tips over to the heated end. After the rod has tipped over towards the heated end and the heating has ceased, the rod cools off, **contracts,** gets lighter on this end, and tips back to the screw end.

It might seem that the heating caused the mass of the heated end to increase, but this is not so. It only increased in length.

2.2.18. THE WEAKENING WIRE

What you need: 1. A length of wire (copper or iron) about 3 m long.
2. A 1/2 - 1 Kg weight (or rock of the same weight).
3. Eight candles or alcohol burners, a meter stick. 4. Two straight-back chairs.



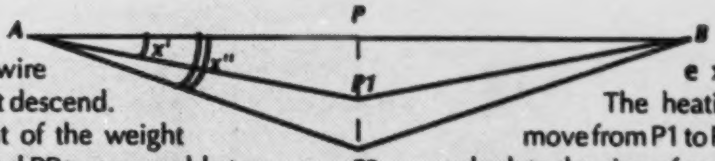
How to set it up

1. Cut a length of about 50 cm off the wire.
2. Attach the remaining wire to two straight-back chairs and keep the wire as straight as possible by moving the chairs out.
3. Attach the 50 cm long wire to the center of the stretched wire, and hang the 1/2 Kg weight at the end of this wire. (You might need some weight on the chairs to keep them from moving—books or students sitting).
4. Tape a small paper arrow to the weight and point it to a ruler, held vertically next to the vertical wire (taped against wall or table).
5. Heat the stretched wire with at least two alcohol burners (have a student assist you in heating one side of the wire—move the burner slowly under the wire along the whole length of it). Observe arrow!

What questions to ask:

1. Why did the weight sag down when the wire was heated?
2. How much did the weight come down?
3. Would the number of burners or candles affect the amount of sagging?
4. Would wires of different materials sag the same distance?
5. How can we calculate from the sagging of the weight how much the wire has stretched?

How to explain it:



The heating of the wire by the burner flames made the wire expand, and this made the weight descend. The heating made the point of attachment of the weight move from P_1 to P_2. By measuring the lengths AP and PP_1, we are able to calculate the size of angle x' from $\text{tg}\, x' = PP_1/AP$, and the length AP_1 from $\sin x' = PP_1/AP_1$. Similarly the angle x" can be obtained from $\text{tg}\, x'' = PP_2/AP1$, and the length AP_2 from $\sin x'' = PP_2/AP_2$. The expansion of the wire is $AP_1 - AP_2$ times 2. **Another way is to use the Pythagorean Theorem.**

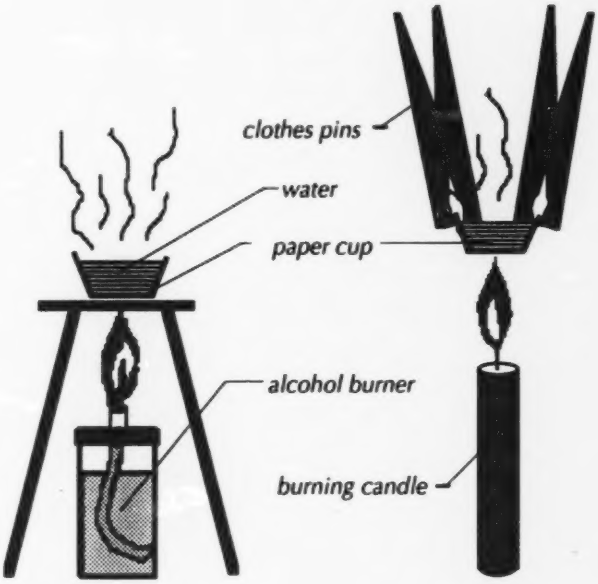
The more burners are used for the heating, the more the weight will sag. Wires of different metals will expand differently and thus result in specific amounts of sagging distances.

2.2.19. BOIL WATER IN A PAPER CUP

What you need: 1. An un-waxed paper cup (cupcake baking cup suits).
2. Alcohol burner and stand, or candle, or stove top.
3. Two clothes pins.

How to set it up:

1. If paper cups are not available, a container can easily be made out of a paper card (3x5"), by folding the four corners up and clipping them with four paper clips.
2. Half fill the paper container with water and place it on the stand (see Sketch A) or use the cloth pins to hold the cup over the flame (Sketch B).
3. Light the alcohol burner or candle, and heat the water until boiling.



What questions to ask:

1. Why doesn't the paper burn?
2. What would a waxed paper cup do if used?
3. Where does the heat of the flame go?
4. How high will the temperature of the water reach?
5. What temperature does it have to reach for the paper to catch fire?

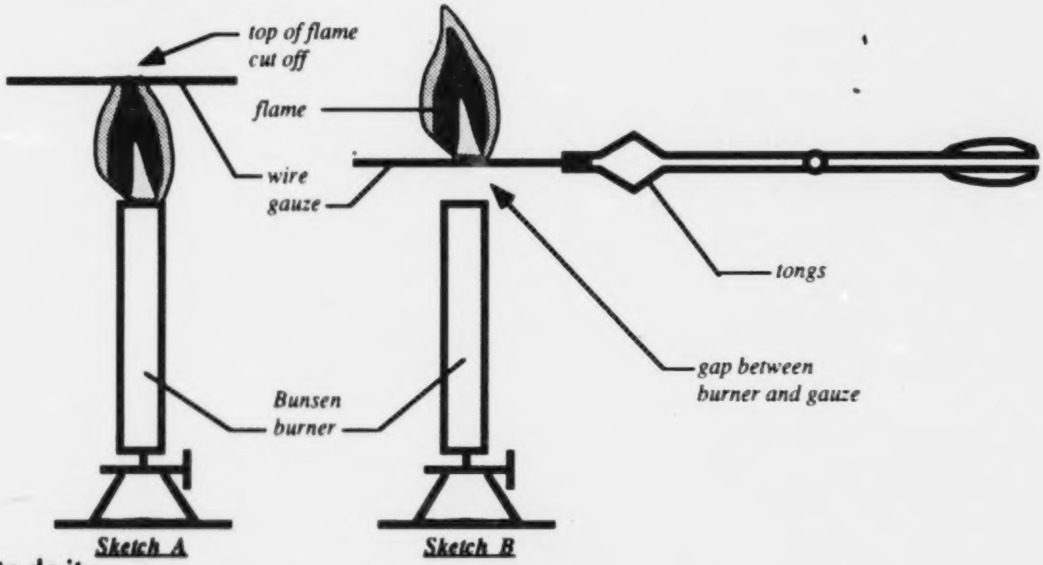
How to explain it:

The heat released by the flame is **absorbed** by the water in the paper cup. It is used to increase the temperature of the water from room temperature to the boiling point, which is 100° C. At this temperature the heat is then further needed to convert the water into water vapor. The temperature of the water will stay at the boiling point (100° C) and not increase that of the cup either, until all the water is evaporated. Because the **kindling point** of paper (the temperature at which paper catches fire) is much higher than 100°C (depending on the thickness of the paper), it will not catch fire before all the water is evaporated. In other words, wet paper will not burn until it is dry. This same principle is applied when "green" wood is burned in fireplaces: it is hard to catch fire until all the sap is driven off.

To get the kindling point of neighboring houses down, water is sprayed on them to prevent them from catching fire, eventhough they are themselves not on fire.

2.2.20. THE BROKEN FLAME

What you need: 1. A Bunsen burner or large candle.
2. Wire gauze (without asbestos) or use the clear part
3. Pair of tongs or tripod.



How to do it:

1. Light the Bunsen burner (leave the flame yellow) or light the large candle.
2. Hold the wire gauze (with a pair of pliers or tongs) in the middle of the flame (top of flame is cut off - see Sketch A).
3. Vary the height of the gauze above the burner or candle - bring the gauze slowly down - until suddenly the flame appears above the gauze.
4. Now raise the gauze slowly and observe the gap between the burner and the gauze! - see Sketch B. What happens if you keep on raising the gauze?

What questions to ask:

1. After holding the gauze in the flame, does the flame immediately appear above the gauze? Why? Why not?
2. How far above the burner (or candle) can the gauze be held in order for the flame still to appear?
3. Do you see the flame below the gauze? Before or after the flame appears above the gauze?
4. What makes the flame disappear below the gauze?

How to explain it:

In the beginning of the demonstration when the gauze was held over the flame, the flame was cut off exactly where the gauze was - Sketch A. This happened because the heat was absorbed and *conducted* away by the gauze, the temperature above the gauze was thus too low to ignite the flame (below **kindling temperature**). Unburned gases (or candle wax vapors) were still present above the gauze, however. After holding the gauze in the flame for a longer time, the gauze is reaching kindling temperature of the gases and the flame above the gauze is suddenly ignited.

After raising the gauze slightly above the burner, a gap (no flame) is observed between the burner and the gauze. This happens because all the heat is absorbed by the gauze and also cool gas is being supplied under the gauze, which keeps it below **kindling temperature.**

HANDS-ON MEANS

DOING IT YOURSELF

AND YOU WILL REMEMBER IT !

Make your own "PAPER MERRY-GO-ROUND"

and you will remember that **air rises when heated** !

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CHAPTER 3

HOW DOES MAGNETISM WORK ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

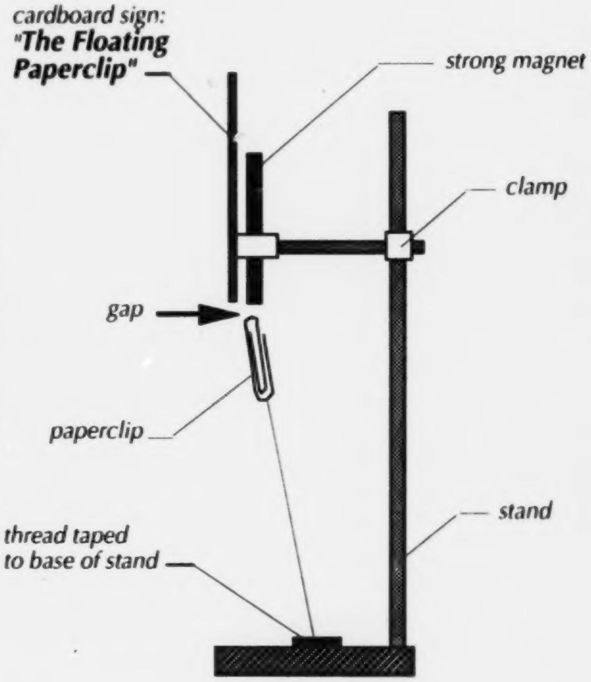
--- Materials that can be magnetized or attracted to a magnet are made up of or contain either iron, nickel, or cobalt.
— Like poles repel and unlike poles attract each other.
— Around a magnet there exists a magnetic field, the magnetic lines of which run from pole to opposite pole.
— A magnet is made up of small dipole particles that are lined up in one direction.
— The North geographic pole of the earth contains South magnetism and the South geographic pole North magnetism.
— The North pole of a compass points North because man named this pole North.
— Magnetic materials can be temporarily magnetized by induction.

2.3.01. THE FLOATING PAPER CLIP

What you need: 1. A rod magnet, stand and clamp.
2. A paper clip and thread (transparent or black).

How to do it:

1. Clamp a rod magnet vertically and tape a cardboard sign, "THE FLOATING PAPER CLIP" in front of it. (The bottom edge should be flush with the magnet.)
2. Tie a paper clip to a thread and tape the other end of the thread to the base of the stand, such that the clip is still held up by the magnet, but leaving a gap between the two.
3. Show to students that no thread is holding the clip up by sliding thin objects through the gap (a ruler, a card, a comb, etc.).
4. Now take a pair of scissors and "cut" the magnetic lines that are holding the paper clip up.



What questions to ask:

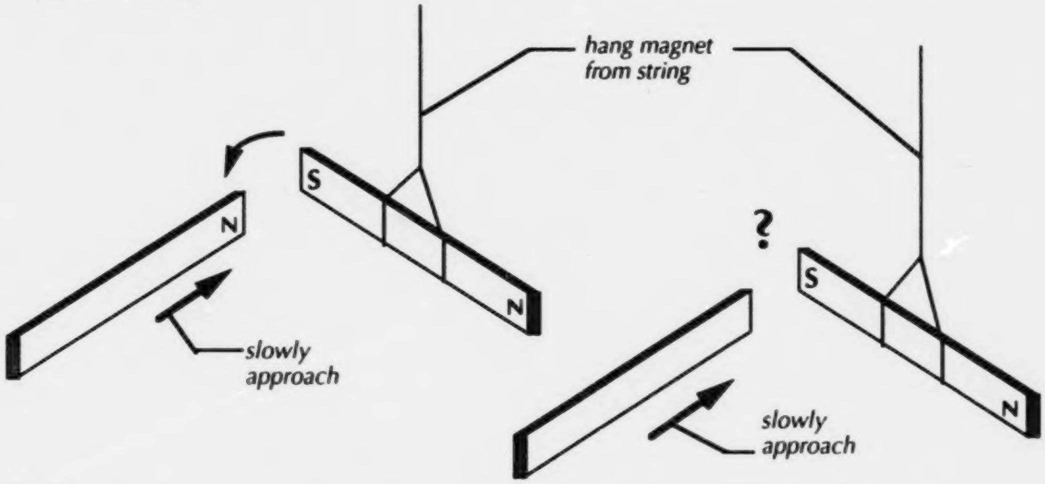
1. What materials could be slid through the gap without dropping the paper clip?
2. What materials will definitely "cut" the magnetic lines?
3. Which coins will go through the gap without dropping the clip?
4. Why do only some dimes (old ones) pass the gap without "cutting" the magnetic lines?
5. What were the scissors actually doing to the magnetic lines?

How to explain it:

The paper clip is held up by **magnetic lines** indeed. When the magnetic lines are prevented from going through the clip, it falls. Materials that can absorb the magnetic lines from the magnet are materials which are iron, nickel or cobalt ,or contain any amount of it (for instance in an alloy). Magnetism originates from within the atom. In the **magnetic materials:** iron, nickel and cobalt, the electrons around the nuclei although paired together, do not completely cancel out the magnetic fields. They could be considered as consisting of minute magnets that are randomly arranged. When these minute magnets are all lined up in one direction, the object can become a strong magnet.

2.3.02. WHICH POLE IS ATTRACTED ?

What you need: 1. Two marked (with N & S) bar magnets.
2. One unmarked bar magnet.
3. A piece of string.



How to do it:

1. Tie a string to a marked bar magnet and let the magnet hang horizontally from the left hand (or from a stand).
2. Approach this free rotating magnet with another marked bar magnet in your right hand. Let students observe what the north and south end of the hanging magnet will do when another north or south end approaches it.
3. Now replace the marked bar magnet in your right hand with an unmarked bar magnet, and ask students which pole will swing towards this approaching magnet?"
4. Wait for students' reactions (some anticipated answers: 'We don't know until you tell us what pole is coming near the hanging magnet').
5. Say: "If I tell you what pole I have in my right hand, can you tell me which one will be attracted to it?"

What questions to ask:

1. Can you make a rule that all magnets will follow?
2. What would the hanging magnet do when approached with a regular steel bar?
3. What can you tell about the approaching bar if the **N** as well as the **S** pole swings towards it?

How to explain it:

The main purpose of this demonstration is to elicit the rule of magnetism — **"Like poles repel and unlike poles attract"** — from the students themselves. By showing them the phenomenon of the magnets as shown in the sketch several times, with different poles approaching the hanging magnet, they should be able to form and understand the concept themselves.

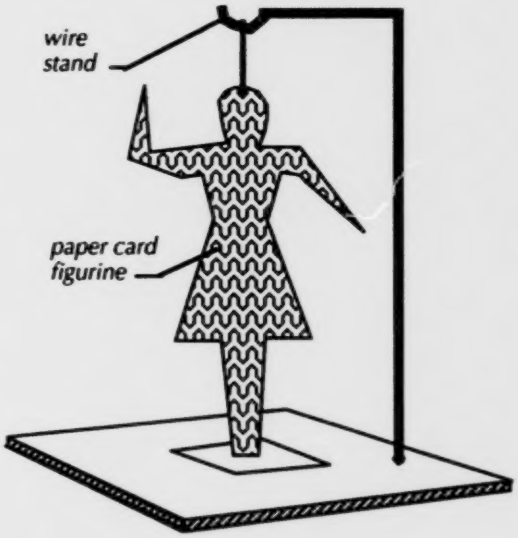
By approaching the hanging magnet with an identical steel bar, which is not magnetized, both poles will be swinging towards it. This happens because the particles in the non-magnetized bar are still randomly arranged and a **north** as well as a **south** pole of a magnet can attract the steel bar. A nail will show the same properties.

2.3.03. THE MAGIC DANCER

What you need: 1. Two small disc magnets.
2. A wooden stand, tape. 3. Paper cards (3x5) & scissors.

How to do it:

1. Construct a stand of wire in a wooden base and cut out a paper card dancer figure.
2. Hang the dancer on the stand from a thread.
3. Tape a disc magnet directly under the figurine and conceal another disc magnet directly beneath the leg of the figurine.
4. Move the dancer a little and observe.



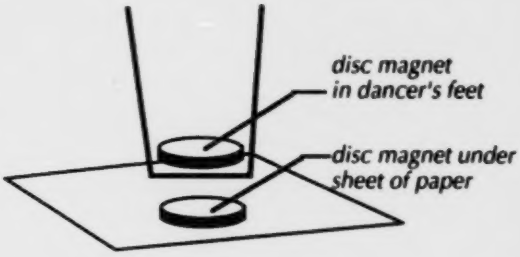
What questions to ask:

1. Why does the figurine keep on moving?
2. How do the magnet poles have to be arranged?
3. Why does the base have to be made out of wood?

How to explain it:

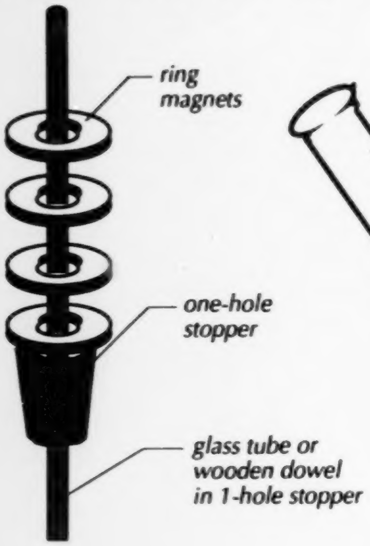
The two concealed disc magnets are placed facing each other with **like poles**, so that they **repel** each other. This way the figurine keeps on bouncing away from the point vertically under it, causing it to move and twirl for quite an extended time. This bouncing away would of course not occur if **unlike poles** were facing each other. The figurine would be immediately **attracted** to the base magnet and does not go anywhere.

If the base of the stand were made out of iron or any other magnetic material, the magnet concealed in the base would lose much of its magnetism and the upper magnet would be attracted to any part of the base and it would stop moving. Any other non-magnetic material could be used to construct this base.

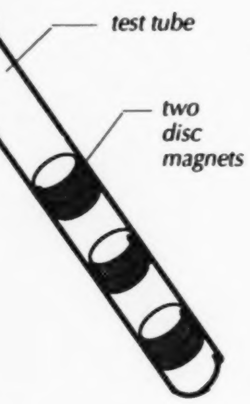

disc magnet in dancer's feet
disc magnet under sheet of paper

2.3.04. THE FLOATING DISCS

What you need: 1. Six or eight small disc magnets (or ring magnets).
2. A test tube (for the discs) or a glass tube in a one-hole stopper (for the rings).



Sketch A



Sketch B

How to do it:

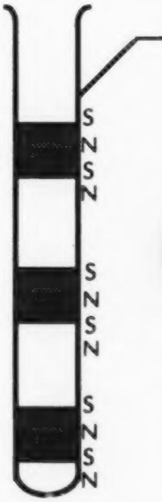
1. Stick the six or eight disc magnets together two by two.
2. Slide the first pair in the bottom of the test tube.
3. Slide the second pair in the tube, such that they repel the first pair. (If they are attracted to the first pair, take all four out, turn the two upper discs upside down and slide them back in the tube).
4. Do the same with the next two pairs of disc magnets.
5. If case ring magnets are used: slide them around the glass tube, such that they repel each other (see Sketch B).

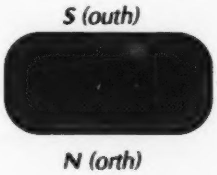
What questions to ask:

1. Why do the pairs of discs stick together?
2. Where would the poles of the disc magnets be located?
3. Assign a letter N or S for each of the poles.
4. How could we get the discs out of the test tube without turning the tube upside down?

How to explain it:

The pairs of discs have **unlike poles** facing each other and therefore they **attract** each other. The poles of the disc magnets are located at its two circular flats, and the 'floating' occurs because the **same poles** face and thus **repel** each other. If the bottom pole is assigned to be North, the other poles have to be in the order as in the sketch on the right, in order to get the 'floating' pair arrangement. The same can be done with the ring magnets.

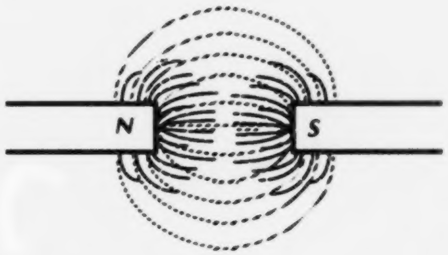


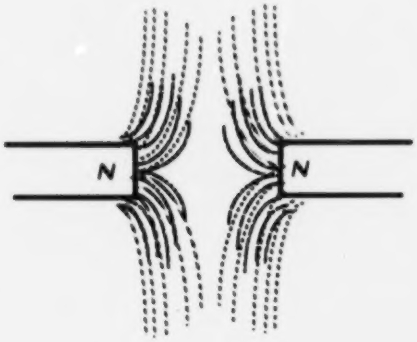


Side view of disc magnet

2.3.05. SEEING MAGNETIC LINES

What you need: 1. Two rod or bar magnets (and other shape magnets).
2. A transparency or glass sheet.
3. Iron filings.





How to do it:

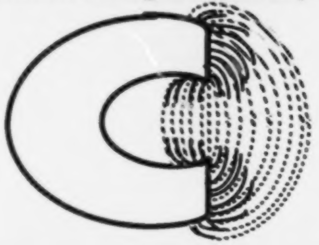
1. Place two bar magnets with the unlike poles about 4-5 cm apart on an overhead projector (if not available: let students gather around).
2. Cover the magnets with a blank transparency and sprinkle some iron filings close to the poles especially. (When an overhead projector is not available, a sheet of window glass or white paper will do.)
3. After sprinkling the iron filings, tap lightly on the transparency (glass or paper).
4. Do the same (step 1 to 3) with the two like poles together or facing each other (Sketch B).

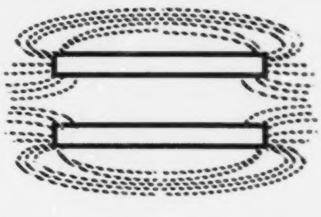
What questions to ask:

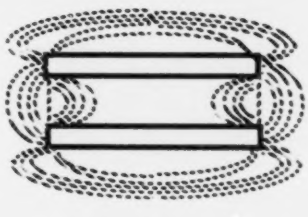
1. What do the two different patterns of lines indicate?
2. How would the magnetic-line-pattern of a horseshoe magnet look?
3. How would the pattern of lines look, if the bar magnets were placed parallel to each other, with like poles next to each other? With unlike poles next to each other?
4. How would the magnetic line pattern of one bar magnet look like?

How to explain it:

Any thin sheet of material that is not magnetic (not iron, nickel or cobalt) can be used to show the magnetic lines with iron filings. The use of the transparency and overhead projector has the advantage, that it can be clearly shown to the whole class at one time. Students should gather around a little closer when it is not projected. These are the patterns that will show up for a horseshoe magnet and the parallel bar magnets:

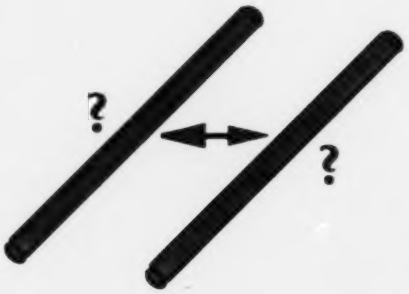






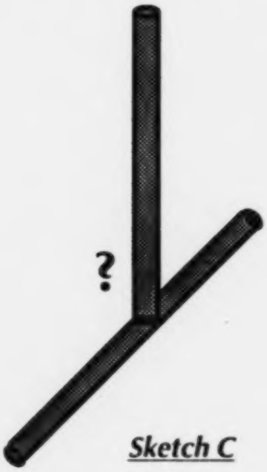
2.3.06. WHICH ONE IS THE MAGNET ?

What you need: 1. A strong bar magnet. 2. An identical steel bar (not magnetized).



Sketch A

Sketch B



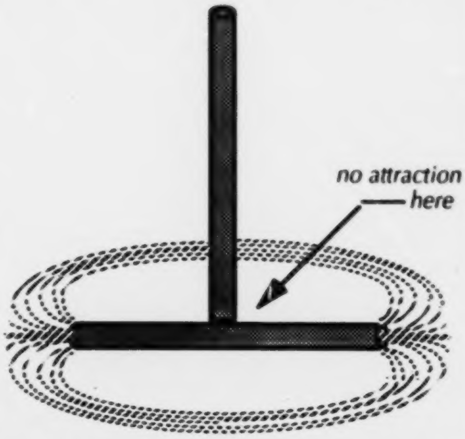
Sketch C

How to do it:

1. Show the students the two identical bars and say: "One of these bars is a magnet. How can we tell which one it is, without using any other materials?"
2. Carry out whatever the students want you to do (let one bar roll on the table attracted to the other bar (Sketch A) or put pole against pole (Sketch B), might be some suggestions.
3. If students do not suggest the set-up of Sketch C, give them a clue to think about the magnetic lines flowing around a bar magnet (Event 3.05.), and ask: 'Where would the magnet be weakest in attraction force?"
4. Then show and demonstrate configuration C.

What questions to ask:

1. Can we tell which one is the magnet with the set-up in Sketch A or B?
2. If the vertical bar attracts the horizontal bar (Sketch C), which one is the magnet?
3. Why would the end of the steel bar (the non-magnet) not attract the middle of the bar magnet?
4. How do the magnetic lines of force flow around the bar magnet?

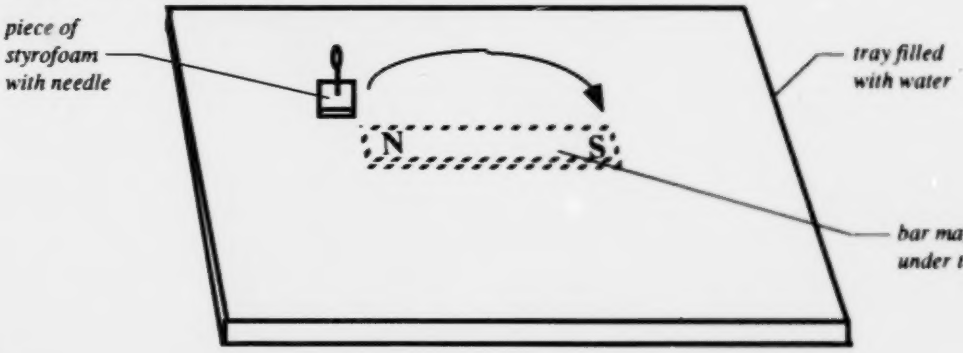


How to explain it:

Whether the bars are placed against each other as in Sketch A or B, there is no way to tell which of the two bars is the magnet, because there is **no repulsion**, as one of the bars is a regular non-magnetized steel bar. The only way to tell which one is which, is by holding the bars as in Sketch C (in a T configuration), as the magnetic field in the center of the bar magnet is weakest. You might say that the two poles of the magnet neutralize each other in the center of the bar.

2.3.07. THE MYSTERIOUSLY MOVING NEEDLE

Materials: 1. One strong bar magnet, a medium size sewing needle.
2. A wide and shallow glass or plastic tray (to hold water).
3. A small cork or small piece of styrofoam.



Procedure:

1. Magnetize the needle by rubbing the North pole of the rod magnet several times from the point towards the hole end (see step 1 under procedure for **Make a Needle Compass).**
2. Fill the tray with water (about 2 cm deep) and place it on top of the bar magnet (propping the sides so the water level stays horizontal).
3. Pierce the needle through half of a small cork or a small piece of styrofoam, such that the sharp end points vertically down.
4. Place this needle near the North pole of the magnet and observe! (make sure that the sharp point just floats 2-3 mm above the bottom of the tray. If it is not, just add some more water to the tray).

Questions:

1. What did you observe the needle doing?
2. What would it do if the needle was placed near the South pole?
3. Would rubbing the needle with the South pole of the magnet make any difference in movement?
4. What difference would it make if the needle was rubbed with the North pole but in the opposite direction (from hole to sharp end)?
5. Why doesn't the needle move in a straight line towards the poles?

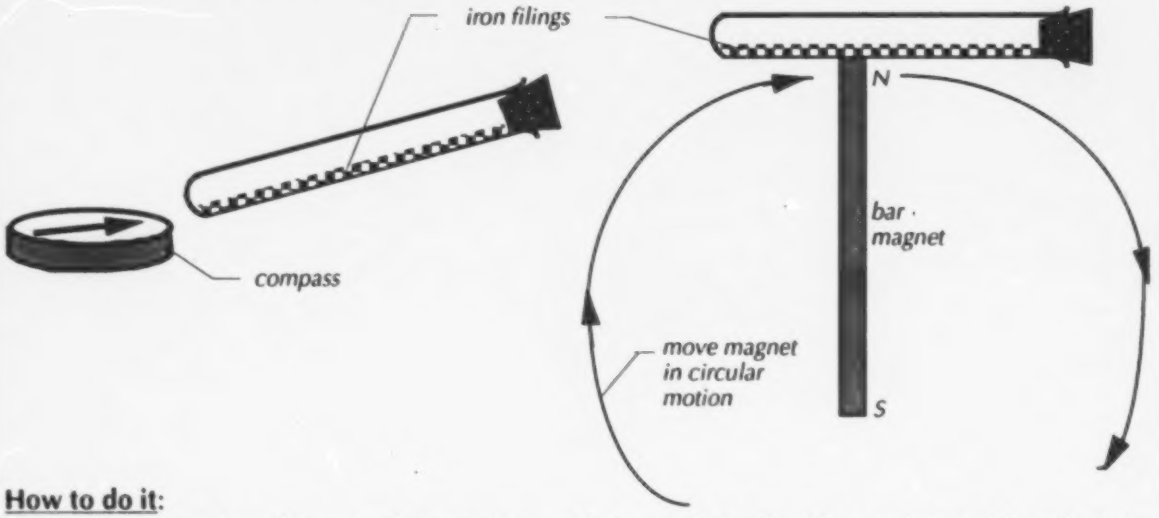
Explanation:

By rubbing the needle with the North pole of the strong magnet from the sharp end towards the hole end, the needle itself will become a magnet, the sharp end being the North pole and the other end the South. After placing the needle vertically on the water surface, it is free to move, and it is thus **repelled** by the North pole and **attracted** by the South pole of the magnet (which is lying underneath the tray). It travels in a curved line following the **magnetic lines** of the strong magnet. The strongest field is closest to the poles of the magnet and thus the movement of the needle is fastest when approaching each of the poles.

A needle that is not magnetized would just move straight towards whatever pole is closest to the needle. What would happen with the needle if we had a horseshoe magnet under the tray of water?

2.3.08. THE TEST TUBE MAGNET

What you need: 1. A test tube and fitting cork/or long thin plastic vial with cap.
2. A strong magnet and iron filings.
3. A small compass (or needle compass: Event 3.09 or 3.10).



How to do it:

1. Place some iron filings in the test tube, cork it and shake the filings while holding the tube horizontally.
2. Bring the end of the tube close to the compass and show that the compass needle is not or very little attracted; also let students note that the same needle end is attracted to the test tube, no matter which end of it is approaching the needle (compass).
3. Now take the strong bar magnet and magnetize the iron filings in the test tube by stroking the bottom side of the horizontally held tube with one pole of the magnet in a circular motion (see Sketch).
4. After stroking the tube with the magnet for about 5-6 times, show that the test tube acts as a regular bar magnet by approaching the compass with the two ends of the tube.

What questions to ask:

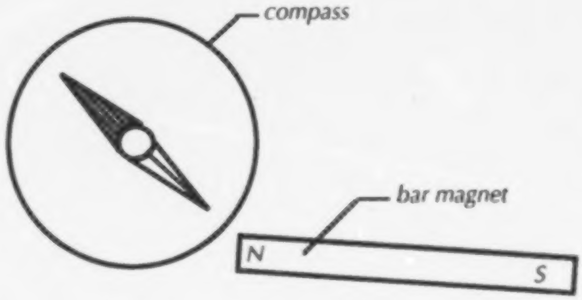
1. Why is the compass needle attracted to the iron filings before the tube was magnetized?
2. Why does the stroking of the test tube have to be done with a circular motion?
3. How can we know whether the iron filings in the test tube are magnetized or whether they are not?
4. How would the compass needle behave, if a regular bar magnet approached the compass?
5. What could we use if we did not have a compass?

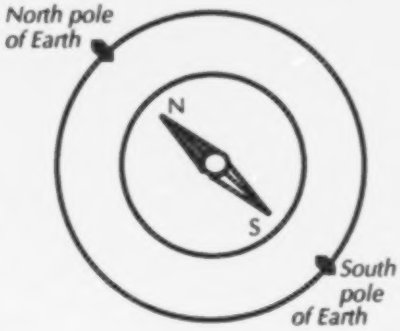
How to explain it:

A bar magnet is made up of very tiny particles that have very weak **dipoles** or North and South magnetism, just like the iron filings in the tube. They are scattered randomly in the bar. When these particles are lined up by stroking with a strong magnet, the bar becomes a magnet. This is demonstrated by the iron filings in the test tube. When the tube is shaken after it is magnetized, the particles are distributed randomly again, and no magnetism is left in the tube.

2.3.09. MAGNETIC CONFUSION

What you need: 1. A small compass 2. A marked bar magnet.





How to do it:

1. Give the compass to the your student and ask: "Which end of the needle is the North end, and which one is the South end?"
2. "How can we find out?" Come around with the marked bar magnet and approach the compass with the North pole of the bar magnet.
3. Now that the student already knows which end of the compass needle is North and which end is South, ask: "Which end of the compass points in the North direction?"
4. "Is North attracted by North? Is this not against our magnetic rule?"

What questions to ask:

1. How did we find out which end of the compass was North?
2. If we did not have the marked bar magnet, how could we find this out?
3. If the marked bar magnet was hung on a string, which pole would point to the North pole of the earth?
4. If there were no marked bar magnets to find in the whole world (which was the case before magnetism was discovered), how would we label the first bar magnet?

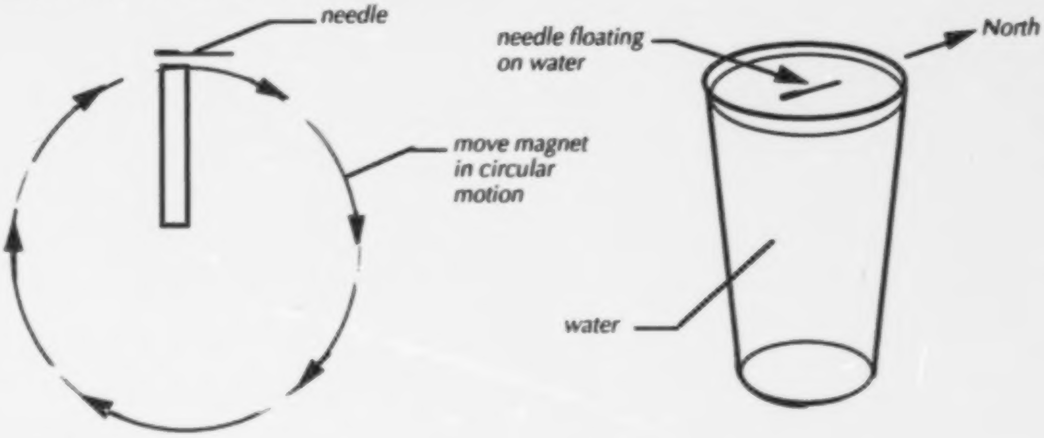
How to explain it:

This activity poses the student with a real discrepancy, especially after learning the magnetic rule: **unlike poles attract and like poles repel.** The fact that the North end of the compass needle points to the North pole of the earth, is because this compass needle end is a **north-seeking** one and thus **named 'North'.** The situation is then that, either the earth's North pole contains South magnetism, or that all North labeled bar magnets are actually the South pole. The most simple fact to remember for students is: that the North end of the compass needle is **named North**, because it is **North-seeking**, in other words, it is pointing to the North.

All bar magnets, when hung from a string, will line up in the North-South direction. The North pole of the bar will point to the North pole of the earth, because it is North-seeking.

2.3.10. MAKE A NEEDLE COMPASS

What you need: 1. A fine sewing needle, a piece of candle.
2. A strong magnet, and a glass or cup of water.



How to do it:

1. Take the needle between the fingers of one hand, and with the other hand rub the pole of the magnet against the needle in **only one direction**. After each stroke, move the magnet away from the needle and approach the needle from the 'eye'-side (Sketch A). Do this about 8 - 10 times.
2. Hold the needle between thumb and forefinger horizontally and approach the water surface as close as possible without touching it, then drop the needle. (When needle sinks, rub it against the candle before floating it, so that it would repel the water).
3. Once the needle is afloat, it will point only in one direction. Test this by approaching the cup with a magnet and removing it.

What questions to ask:

1. When stroking the needle with the magnet, why can't we rub the needle back and forth against the magnet?
2. When rubbing the needle from eye to point with the south pole of the magnet, which end of the needle will point north?
3. Which end of a compass needle will point north?

How to explain it:

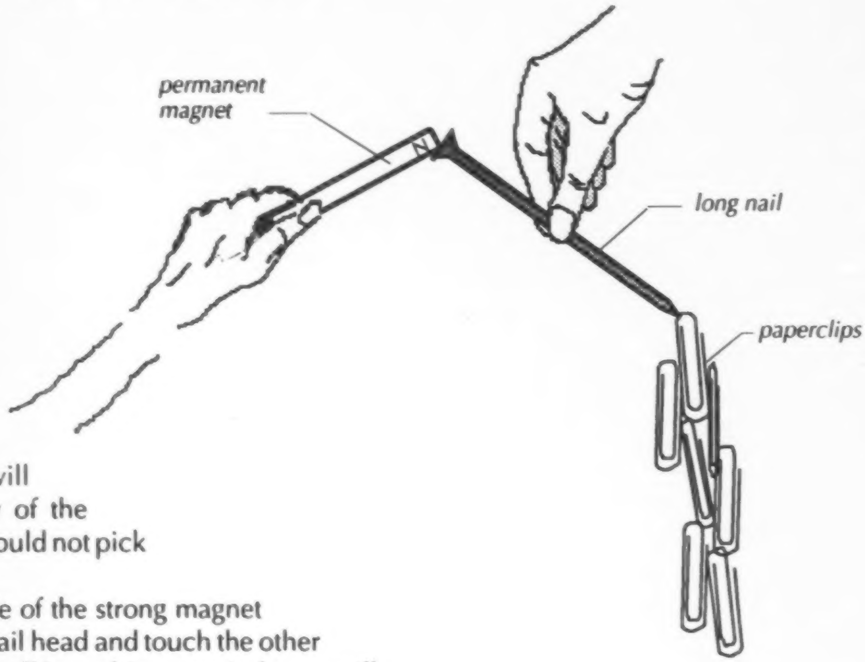
The rubbing of the needle with one pole of a magnet should be done only with one-direction strokes, because the purpose of the rubbing is to **align** the tiny particles of the needle in only **one direction.** When the rubbing is done with a back and forth motion, this alignment is not achieved as well. When the south end of the magnet is used to rub the needle from eye to point, the point will be the north pole of the needle, and thus this will point north. This is not because 'north' is attracted by 'north', but because the earth's north pole contains 'south' magnetism.

Other ways to suspend the magnetic needle are: hanging it on a thread in a jar from a glass rod or wooden stick, which is resting on the opening of the jar; floating it on a wide flat cork disc on the water surface is another way.

2.3.11. THE TEMPORARY MAGNET

What you need: 1. A strong bar magnet. 2. A long iron nail.
3. Paper clips or thumbtacks or small nails.

How to do it:



1. Place some paper clips, thumbtacks or small nails on a sheet of paper .
2. Touch the point of an iron nail to the heap of paper clips and see if it will pick up any of the objects (it should not pick up any).
3. Hold one pole of the strong magnet against the nail head and touch the other end to the small iron objects again (some will be picked up now: see Sketch above).
4. Remove the magnet now from the nail (the small objects will drop).
5. Repeat point 2, 3, and 4 to show the temporary nature of the nail as a magnet (induction).

What questions to ask:
1. What made the nail become magnetic?
2. Could a copper or aluminum nail do the same thing?
3. If the north pole of the magnet were touching the nail, what pole would the nail point be?
4. What is the process of temporary magnetization called?
5. What other materials can be temporarily magnetized?

How to explain it:

The magnetic field surrounding the strong magnet can **temporarily magnetize** objects made of iron, nickel or cobalt. When this happens, it is said that the object is magnetized by **induction** and that the object is a **temporary magnet.** When the north pole of the magnet touches the nail head, this becomes the south pole and the nail point becomes the north pole.

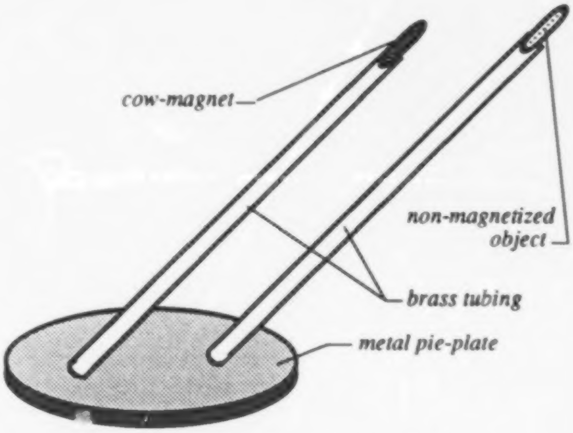
The particles (dipoles) of the nail are lined up in one direction and the whole nail becomes a magnet for a short time. As soon as the permanent magnet is taken away, the particles revert back to their random distribution and the nail's magnetism disappears.

2.3.12. THE DROPPING RACE

Materials: 1. Two 3 ft (1 m) long brass tubing, 1/2" (1.3 cm) in diameter.
2. A cow magnet (with a diameter slightly smaller than the tube)
3. Other small cylinders similarly shaped as the cow magnet, like an A-battery or a cap of a marker, etc. 4. An aluminum pie plate or metallic jar lid.

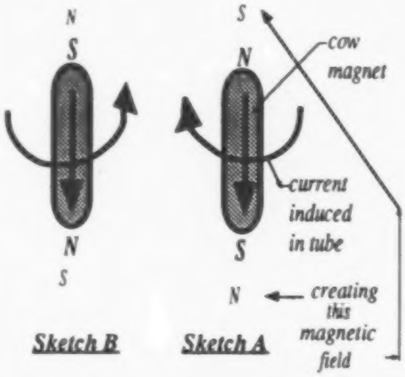
Procedure:

1. Give one of the brass tubes to a volunteer (student) and let him choose any of the objects to race with you, who has the cow magnet.
2. The object of the race is to let the object stay in the tube as long as possible, so that a later click on the metal plate indicates the winner. Tell the students that they may change anything (like: dimensions, weight, etc.) of the object, as long as it will fall freely through the tube.
3. Hold the brass tube almost vertically above the metal plate and get ready to let the cylindrical object slide into the tube. Let the student do the same.
4. Tell the students: "On the count of three, let go of the object! Listen to the clicks!



Questions:

1. What are the variables that are working on this race?
2. Which is the manipulated variable? (the variable that we chose to change?)
3. Which is the responding variable? (the variable that we measured?)
4. What made the cow magnet always win from the other objects?
5. If the brass tube was a coil of wire, what would the falling magnet induce in the wire?
6. What would a circular current in the tube change the tube into?
7. Would flipping the polarity of the magnet have any influence on the falling rate?
8. What variable can we change to let the magnet fall even slower?



Explanation:

The cause for the cow magnet to slow down in the falling rate is the **induction** of a current or electron flow in the tubing perpendicular to the direction of the fall. The falling magnet causes a **change of the magnetic field**, which therefore induces a current in the tube (just like in a coil of wire). These currents turn the tube into a magnet with opposite poles, only at the place where this change is taking place. The falling cow magnet is therefore slightly held back in the fall. (see Sketch A). When the magnet is turned upside down and then released, the opposite current is induced and an opposite field is created, also holding back the magnet in its movement. (See Sketch B).

The variables that are working on this particular race are: tube dimensions, magnet dimensions, cylindrical object dimensions, slant of the tube, moment of release, etc. The manipulated one here is of course whether the falling object is magnetized or not, and the responding one is the time the object took to come out of the tube. This slowing down of the falling rate can be increased by 1. Increasing the strength of the magnet, 2. Slanting the tube more, 3. Lengthening the brass tubing, etc.

IF YOU HAD **FUN** DOING IT

YOU WILL CERTAINLY

REMEMBER THE CONCEPT

MUCH **LONGER!!**

Having fun in making : "THE PAPER MERRY-GO-ROUND"

CHAPTER 4

WHAT IS STATIC ELECTRICITY ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

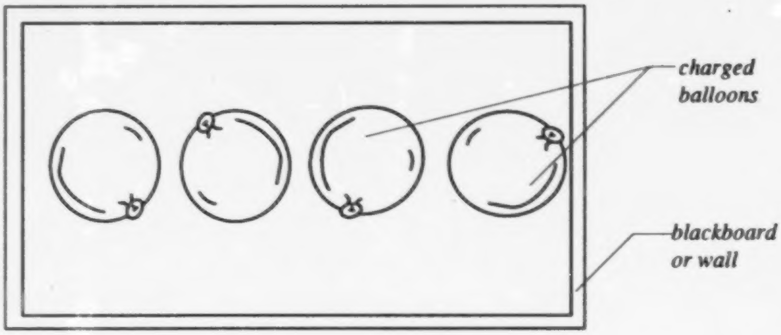
a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

— Rubbing certain objects will result in the removal of electrons and a build up of positive or negative charges.
— Certain uncharged objects are attracted by charged objects.
— There are two kinds of static charges: positive and negative.
— Certain objects may be charged by induction.
— Capacitors are collectors of small static charges.

2.4.01. THE IMAGINARY SHELF

What you need: 1. Three or four balloons.
2. A clean blackboard or dry wall space.

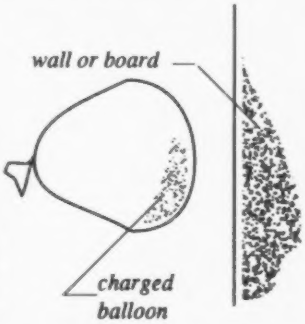


How to do it:

1. Blow three or four balloons up. Tell students that you constructed an imaginary shelf on the blackboard.
2. Rub the balloons carefully (do not press too hard) against your sleeve or shirt, as if cleaning the dust off the balloon, then stick it to the blackboard in a horizontal row.
3. When students catch on about the rubbing of the balloons, have them try to make a second lower 'shelf' with other balloons rubbed against their hair or shirt.

What questions to ask:

1. How did the balloons get to stick to the board?
2. What did the rubbing do to the balloon?
3. Try rubbing the balloon against wool, silk, cotton, or hair. Do you find any difference in the static charge built up?
4. Why do you think the balloons will stick better to the wall on a very cold winter day than on a rainy day?
5. What are other materials that can be charged by rubbing?
6. Can the balloons stick to the walls indefinitely?

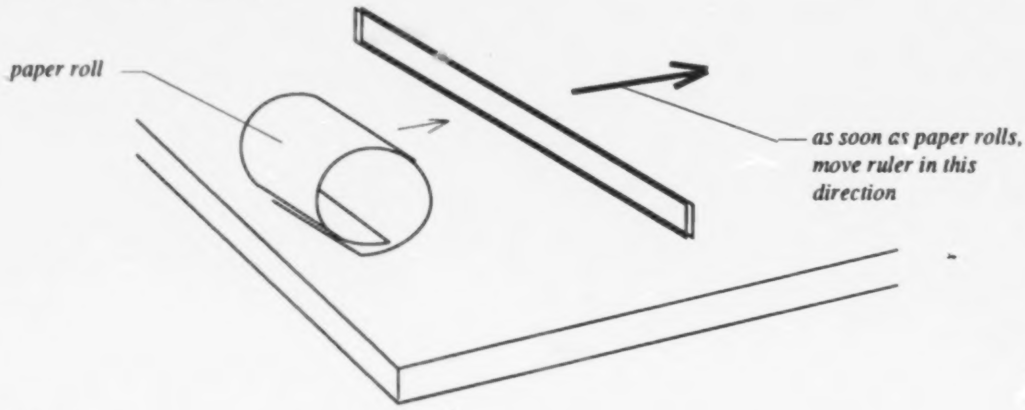


How to explain it:

By rubbing the balloons, the material that was rubbed against it lost some electrons, and thus the balloon obtained an excess of electrons, which means that it has a negative charge. The easier the material used to rub the balloon is able to lose electrons, the easier the balloon gets charged. Wool, cotton or hair are the most common materials to charge the balloons. When the negatively charged balloon approaches the board, the negative charges are repelled and thus a positive charge is induced at the spot where the balloon touches the board. Because of this, the balloon sticks to the surface of the board. Over a longer period of time, electrons will transfer from the balloon to the board and so the balloon gets neutralized and falls to the floor. The losing of the excess charge occurs easier in damp weather, and this is the reason why it is easier to build up charges in winter, when there is very little moisture in the air.

2.4.02. THE MAGNETIC RULER

What you need: 1. A regular plastic ruler and handkerchief.
2. A short thin strip of paper.



How to do it:

1. Make a small roll (about 2 cm diameter) from the strip of paper, so that it can roll over a smooth surface.
2. Take the ruler in one hand and the handkerchief in the other, and rub the ruler with it vigorously.
3. Approach the paper roll slowly until it moves, then move it away from the roll (try to keep pace with the rolling of the paper).

What questions to ask:

1. What initiated the attraction of the paper to the ruler?
2. Is the ruler or the paper magnetic?
3. Can static electricity be considered a force?
4. Where did the initial energy originate?

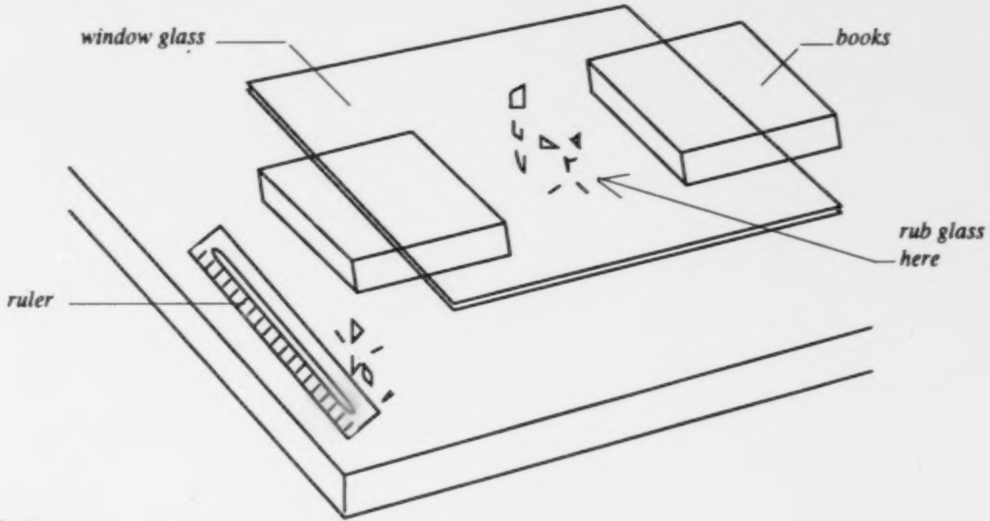
How to explain it:

The rubbing of the ruler was **muscle energy**, or **mechanical energy**, turned into static electricity. The ruler is charged with an excess of negative charges and approaching the uncharged roll of paper , the latter gets attracted to the ruler. Almost anything can be rubbed and charged; some materials are easier to charge than others. The paper roll is attracted to the charged ruler, because the opposite charge is being induced in the paper and an attraction occurs. Any attraction resulting in a movement of an object shows that a force is involved, thus **electrostatic energy is a force.** This can easily be observed, where the paper cylinder rolls from one end of the table to the other, as a result of the attraction of the charged ruler.

Static electricity charges with their attraction and repulsion properties are often confused with magnetic properties. These are two separate and distinct entities. The first is obtained by the removal or addition of electrons by mechanical means (rubbing), and the latter by sorting or arranging the randomly distributed magnetic fields of the tiny particles (dipoles) of the material in one direction.

2.4.03. THE PAPER JUMPING JACKS

What you need: 1. A piece of window glass, a wool rag.
2. A plastic ruler and a handkerchief.



How to do it:

1. Place two books of the same thickness about 10 cm apart.
2. Put some small paper snips between the books and cover them with the piece of window glass.
3. Rub the top of the glass with the wool rag (do not push too hard) and let students observe the paper snips or paper bits..
4. When window glass is not available, use the plastic ruler and rub it with a handkerchief. Approach the paper snips and observe them jump up to the ruler and fall down again.

What questions to ask:

1. What did the rubbing do to the glass or plastic?
2. Why did the paper snips jump up and down?
3. What other materials can be used instead of the paper snips?
4. What other materials can replace the glass or the ruler?

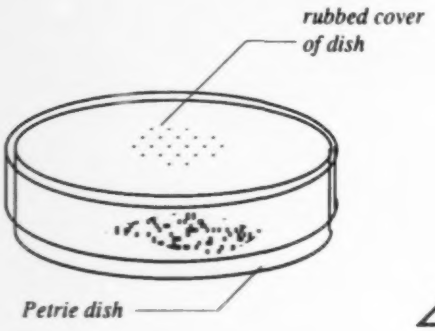
How to explain it:

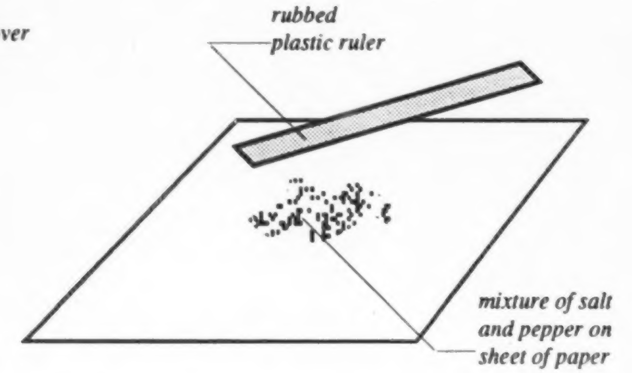
By rubbing the window glass or plastic ruler, negative charges are built up on the glass and ruler. The paper snips are **attracted** to this charge, because the opposite charge is **induced** in them. At the moment that they touch the glass or ruler, the electrons can migrate to the paper; this gives it the same charge and thus they are suddenly **repelled**. As soon as they are back on the table, the paper snips lose this excess charge to the table top, leaving them neutral, and the process can start all over again. This jumping back and forth from table to glass sheet can occur in very quick succession or it may take a longer time.

Other materials to replace the paper snips would be: confetti, pepper, cork powder, fine dry sawdust, foam packing material, etc. Instead of the glass sheet or the ruler, we may also use: a blown up balloon, a transparency (for an overhead projector), a plastic comb, or any other plastic object, etc.

2.4.04. SEPARATE THE PEPPER FROM THE SALT

What you need: 1. Table salt and ground pepper.
2. A plastic petri dish, flannel or wool cloth.
3. A plastic ruler, flannel or wool cloth.





How to do it:

1. Place some salt and pepper in the plastic petri dish and put the cover on. Shake the two granulated substances and mix them. Ask the students: "How can I separate the pepper from the salt without using water?"
2. Rub the cover of the dish with the flannel or wool cloth (or your dry palm of the hand) and turn the dish upside down for a short moment (the pepper should stick to the cover).
3. The pepper can also be separated by placing the mixture on a sheet of paper and holding a plastic ruler that was rubbed with the wool cloth, over the mixture (the pepper should fly up and stick to the ruler).

What questions to ask:

1. What made the pepper stick to the dish cover or ruler?
2. What did the rubbing do to the dish cover or ruler?
3. Why did only the pepper stick to the rubbed surfaces?
4. What would be another way to separate the two substances?

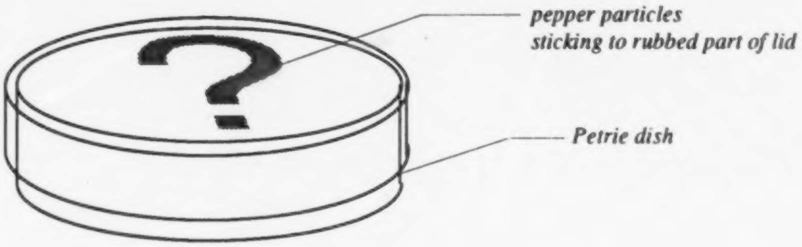
How to explain it:

By rubbing the plastic surfaces with the wool cloth, these surfaces were **charged** with static electricity (from the excess electrons left on the plastic by the wool). The **uncharged** pepper particles got attracted to these surfaces, as opposite charges were induced in them, whereas no charges were induced in the salt particles.

Another way of separating the two substances is to sprinkle the grains of the mixture over the water surface in a container. The salt would sink and the pepper particles would float on the water surface, which could be scooped out. The salt will recrystallize after the water evaporates.

2.4.05. THE PEPPER REPRODUCTION

What you need: 1. A plastic petri dish and lid. 2. A piece of wool cloth
3. A pepper shaker. 4. Paper and scissors.



How to do it:

1. Give the petri dish and the wool cloth to the student.
2. Have them place a pinch of pepper in the petri dish, put the cover on and scatter the pepper over the bottom.
3. Let the student take a piece of paper, the size of the plastic dish and cut out a stencil from it (a letter or any shape).
4. Have him/her, while holding the paper stencil against the top of the dish, rub the open area with the wool cloth vigorously.
5. Now have him/her remove the stencil and invert the dish and then turn it right side up. Ask: "What do you see sticking to the cover?"

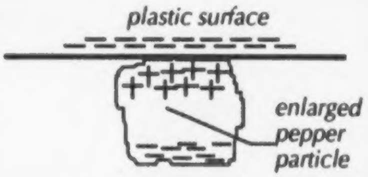
What questions to ask:

1. Why did the pepper stick only to the rubbed parts of the lid?
2. What charge did the pepper have?
3. Why did the pepper stay attracted to the plastic?
4. What are the industrial applications of this principle?

How to explain it:

The paper stencil allowed rubbing of the plastic lid at certain confined areas. Only these areas were **charged** and thus the pepper, which was **uncharged**, was attracted to the charged areas. The pepper particles stayed attracted, because they are electrical insulators and also because they are irregularly shaped. It is thus not so easy for the electrical charges to transfer themselves from the plastic to the pepper particles.

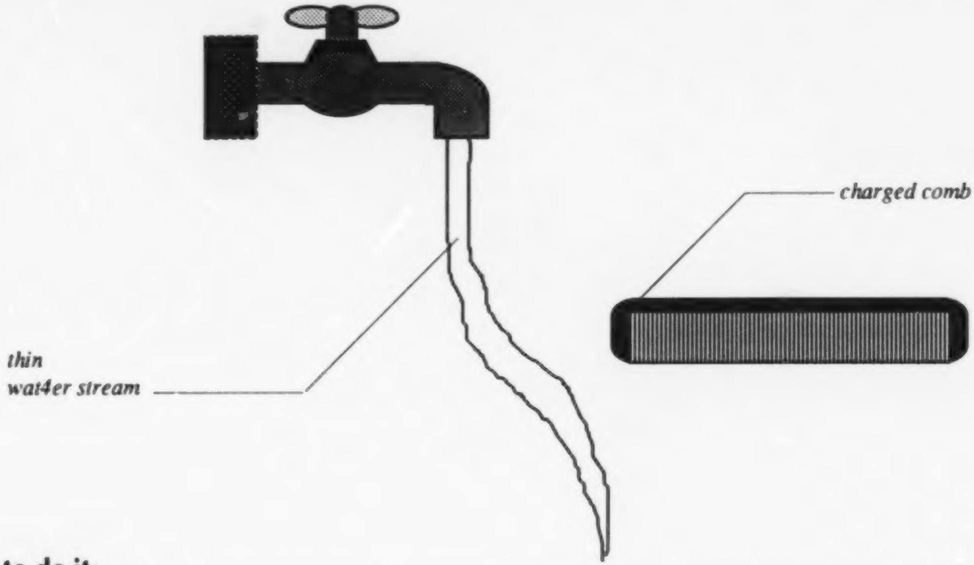
Rubbing the plastic with the wool created negative static electricity, which induced positive charges on the upper side of the pepper particles. (see Sketch on the right).



Industrial applications of this principle can be found in photocopying, removing of dust from exhaust fumes and smoke stacks, industrial painting (paint particles negatively charged and target strongly positively charged).

2.4.06. BEND THE WATER STREAM

What you need: 1. A large plastic comb. 2. A wool, flannel, or felt cloth.
3. A small water stream (from tap or small hole in a can).



How to do it:

1. Open the tap and adjust it such that a small stream of water runs out of the tap (or hold a leaking can with water above a bucket).
2. Rub the comb with a wool, flannel or felt cloth and hold the back of the comb about 2 cm from the stream (move the comb slowly closer to the stream if it is not attracted to it).
3. Make sure that students observe the stream being bent, as a side view. In order to do this, approach the stream from different sides.

What questions to ask:

1. Why did the water stream bend towards the comb?
2. Was it a magnetic force that attracted the water?
3. What other materials can we use instead of the comb?
4. Would a larger stream of water also be bent?
5. What would happen if the charged comb got wet?

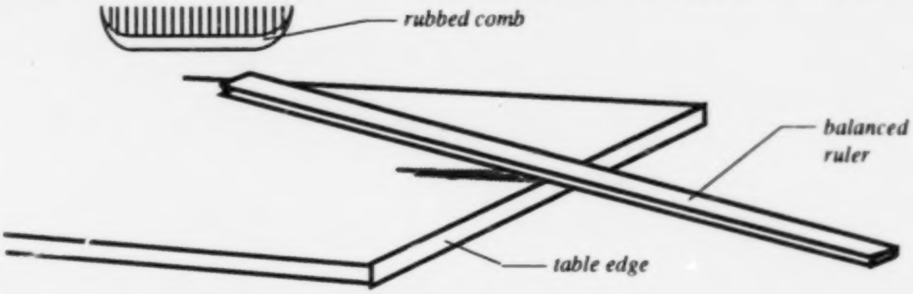
How to explain it:

The charged comb **induces** an opposite **charge** in the water stream and this latter therefore gets attracted by the comb. The mass has to be small enough for the electrostatic charge to move it. The static attraction force is relatively small and thus larger masses are not moved. This is why the water stream has to be small enough so that it can be attracted by the charged comb.
A larger stream needs a much larger static charge to bend.

It is suggested not to get the comb wet. The water would take away all charges and it would be very hard to get the comb recharged with static electricity. Other materials that can be used instead of the comb are: a balloon, hard rubber, a ruler, a glass rod rubbed by silk, etc.

2.4.07. THE ELECTRIC METER STICK

What you need: I. A wooden meter stick. 2. A plastic comb, a piece of flannel or wool.



How to do it:

1. Find a table with a rather sharp edge and let half of the ruler protrude over the edge of the table.
2. Tip the ruler down over the edge, and by pulling it more or less over the edge, let the ruler balance in a slanted position. (see Sketch above).
3. Rub the piece of flannel over the comb and approach the higher end of the ruler with the charged comb.
4. Now touch the upper end of the ruler with the charged comb and wait a bit till the ruler stops moving.
5. Rub the comb again and approach the same end of the ruler that was touched before. Which way does the ruler move now?

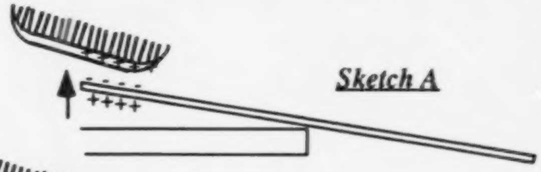
What questions to ask:

1. Which way did the upper end of the ruler move when first approached with the charged comb?
2. Was the ruler end attracted or repelled by the comb?
3. After touching the same end of the ruler with the charged comb, was the ruler attracted or repelled by the comb?
4. If the comb was positively charged, can you explain in terms of moving electrons why the ruler behaved the way it did before it was charged? After it was charged (touched by the comb)?

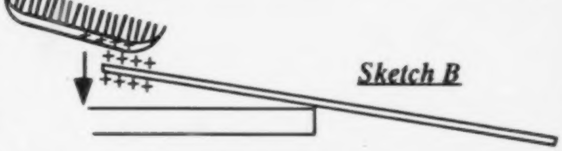
How to explain it:

The wooden ruler balances on the edge of the table on its **center of gravity** and becomes a very sensitive balance. A minute force will tip the ruler up or down on one side.

By rubbing the comb with a piece of flannel, it gets **charged** with static electricity (most likely positive). Approaching the **uncharged** ruler with the positive charge attracts the negative charges in the ruler towards the comb. As negative is attracted by positive, the ruler tips up (Sketch A). Touching the ruler with the comb withdraws the negative charges out of the ruler and leaves it positively charged. The second time we approach the ruler with the comb, the ruler moves down (see Sketch B).



Sketch A

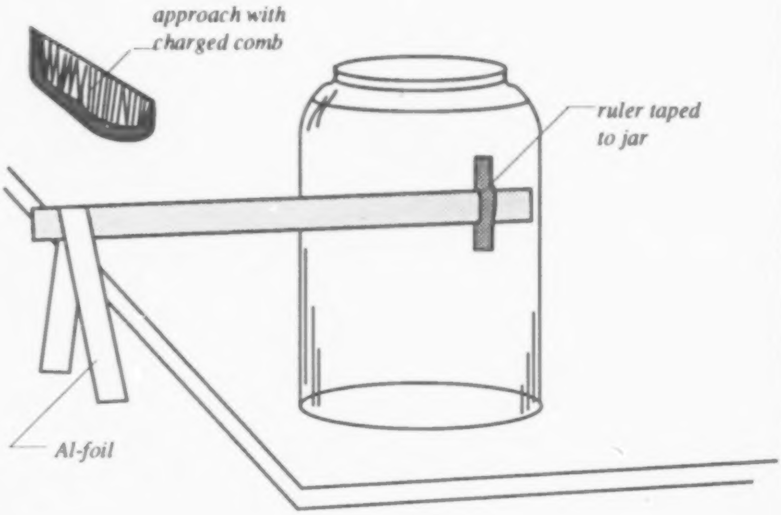


Sketch B

2.4.08. THE ALUMINUM FOIL ELECTROSCOPE

What you need: 1. A strip of aluminum foil, masking tape.
2. A plastic ruler (30 cm), an empty jar. 3. A plastic comb and wool cloth.
4. A glass rod and silk cloth.

How to do it:

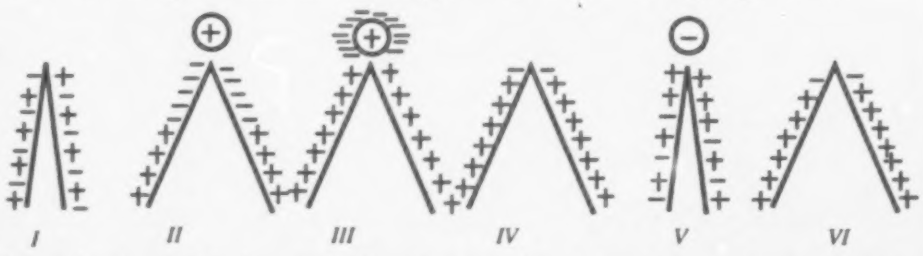


1. Tape the ruler horizontally to the side of the jar like in the Sketch.
2. Fold a strip of aluminum foil double (about 2 cm wide and 20 cm long) and let it hang over the end of the ruler.
3. Make sure that the foil strips are hanging very close to each other (this can be done by folding or rubbing/smoothening the strips).
4. Rub the comb with a wool cloth and approach the top of the strips with it (strip ends open), and withdraw comb (strip ends close).
5. Rub the comb again with a wool cloth, approach the top of the strips and touch it (strip ends will stay open).
6. Rub the glass rod with a silk cloth and approach the top of the charged electroscope with the glass rod (strip ends close), then withdraw the charged rod (strip ends open again).

What questions to ask:
1. What happens to the charges in the Al-foil when approached with a positive charge?
2. Why did the Al-strips stay open when touched with the charged comb?
3. What happened to the charges of the foil when approached by the charged glass rod?

How to explain it:

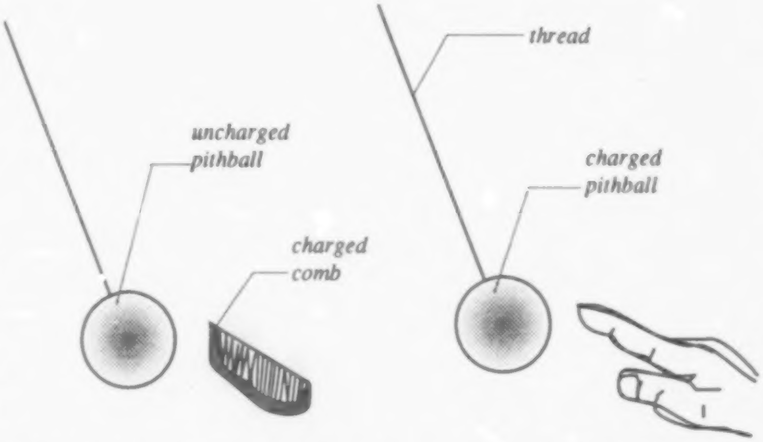
The sequence of flow of charges in the aluminum foil is best explained in the following sketches: I) Uncharged strips. II) Foil strips **induced.** III) and IV) Touching and removing the charged comb leaves foil strips charged. V) Approaching the positively charged foils with the glass rod neutralizes them. Vi) Removing the glass rod makes the foil strips repel each other again, because of the same negative charge leaving the tips of the foil.



2.4.09. THE CONFUSED PITH BALL

What you need: 1. A pithball and thread (the pithball can be made out of a styrofoam ball covered with pencil lead). 2. A plastic comb and a wool cloth.

How to do it:



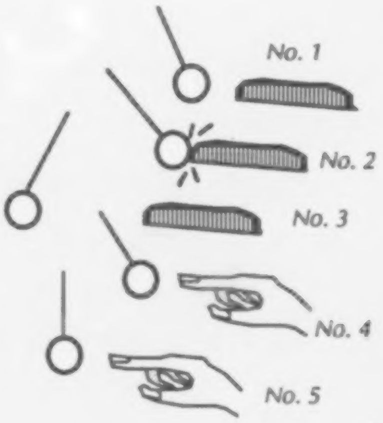
1. Suspend the pithball from a thread attached to a stand.
2. Rub the comb with the wool cloth and ask the students: "What will the pithball do when it is approached by the comb?"
3. Bring the comb near the suspended pithball: show that indeed the ball is attracted towards it.
4. Show this attraction several times without touching the ball. Now come a little closer to the ball with the comb and let them touch each other.
5. Now approach the charged ball with your finger.

What questions to ask:

1. What caused the ball to be attracted by the comb?
2. If the comb was negatively charged, what charges were induced in the pithball?
3. What made the ball suddenly repel the charged comb?
4. What charge does the repelling ball have?
5. Why is the charged ball attracted by the finger?
6. What happens after the charged ball is touched by the finger?

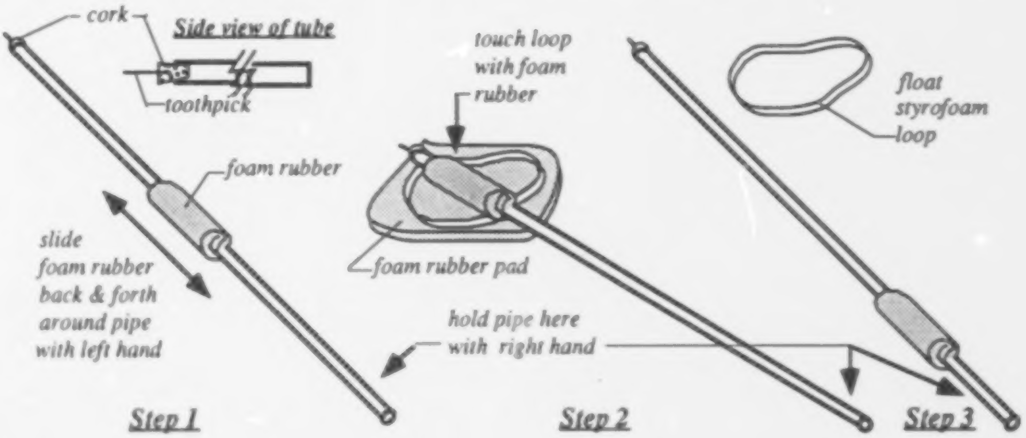
How to explain it:

1. When the comb is approaching the ball, there is an attraction, because a charged object attracts an uncharged object (the pithball) (Sketch 1).
2. As soon as the comb touches the ball, charges of the comb are transferred to the ball (Sketch 2).
3. The ball is now repelled because like charges repel.
4. In bringing the finger close to the charged ball, it is attracted to the finger (uncharged object) (Sketch 4).
5. As soon as the ball touches the finger, the charges are neutralized and there is no attraction nor repulsion by the finger (Sketch 5).



2.4.10. THE LEVITATION ACT

What you need: 1. A hard plastic pipe (PVC) 3/4" x 3 ft long. 2.Two pieces of foam rubber (1x5x5"). 3. A thin strip of flexible styrofoam (from wrapping material). 4. A small cork to fit in the pipe. 5. A toothpick.


cork
Side view of tube
toothpick
foam rubber
slide foam rubber back & forth around pipe with left hand
Step 1
touch loop with foam rubber
foam rubber pad
hold pipe here with right hand
Step 2
float styrofoam loop
Step 3

Procedure:

1. Fit the cork in one end of the pipe and push the toothpick end into the center of the cork (see sideview of tube, part of *Step 1*).Wrap one piece of foam rubber around the pipe and tape it.
2. Make a continuous loop out of the thin strip of styrofoam by taping the ends together, and place it on the other foam rubber piece.
3. Hold the pipe in one hand and rub it back and forth with the foam rubber in the other hand.
4. Leave the foam rubber at the cork end of the pipe and touch (roll) the foam rubber to the styrofoam strip (see *Step 2*), then slide the foam rubber back to where the right hand holds the pipe.
6. Now pick up the styrofoam strip with the end of the toothpick and throw the strip in the air. Immediately move the pipe below the slowly falling styrofoam strip and balance it above the pipe by changing the angle and/or moving it sideways. (see *Step 3*) .

Questions:

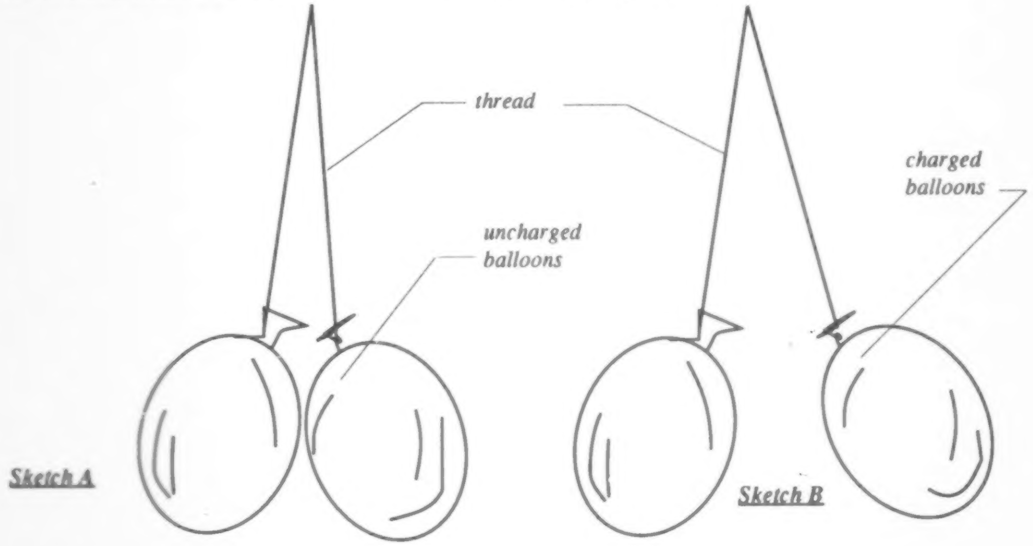
1. What is the function of the foam rubber wrapped around the PVC pipe?
2. What do we need the other foam rubber piece for?
3. What do we create on the pipe by rubbing it with the foam rubber?
4. What force kept the styrofoam strip floating above the PVC pipe?
5. If we call the charge created on the pipe positive, what charge is created on the foam rubber?
6. Why do we charge the styrofoam strip with the foam rubber and not with the pipe?
7. When approaching the styrofoam strip with the positively charged pipe, how do the charges shift in the styrofoam strip?
8. Why can't we pick the styrofoam strip up with our fingers?
9. What other materials could we use instead of the styrofoam strip?

Explanation:

Since electrons or negative charges are more movable, we may assume that a positive charge is left on the pipe by the rubbing action. The inside of the foam rubber is thus negatively charged, and because it is an **insulator, -a substance where electric charges cannot flow easily** -the outside of the foam rubber is positively charged. When we approach the styrofoam strip with this positively charged foam rubber, all the negative charges in the strip are attracted to the surface and when touching occurs, transfer of electrons takes place and the strip is left temporarily positively charged. Now that both pipe and strip are positively charged, we can balance the strip above the pipe and the **repulsion force** will keep it suspended above the pipe, provided the strip is light enough in weight. A very light feather or other insulating material may replace this styrofoam strip. Picking up the strip with our hands will neutralize the strip since we are conductors of electrons and thus it is important to pick the strip up with the tip of the toothpick.

2.4.11. THE BALLOON ELECTROSCOPE

What you need: 1. Two identically shaped balloons of the same size.
2. A wool cloth and thread. 3. A water sprayer (bottle).



How to do it:

1. Blow two identical balloons up to about the same size and tie a thread to each of them.
2. Hold the two threads together and show that the balloons will hang against each other (without any rubbing beforehand) (Sketch A).
3. Now let a student hold the threads, rub the balloons with the wool cloth, and let them hang back (balloons will not touch: Sketch B).
4. Spray a mist of water against the balloons and they will fall back against each other like in Sketch A).

What questions to ask:

1. Why did the balloons repel each other after the rubbing?
2. Why did the balloons fall back against each other after spraying?
3. How else could we let the balloons fall back against each other?
4. What needs to be done to have the balloon fall back?
5. During which time of year would it be best to do experiments on static electricity?
6. What is damp weather doing to the electric charges?

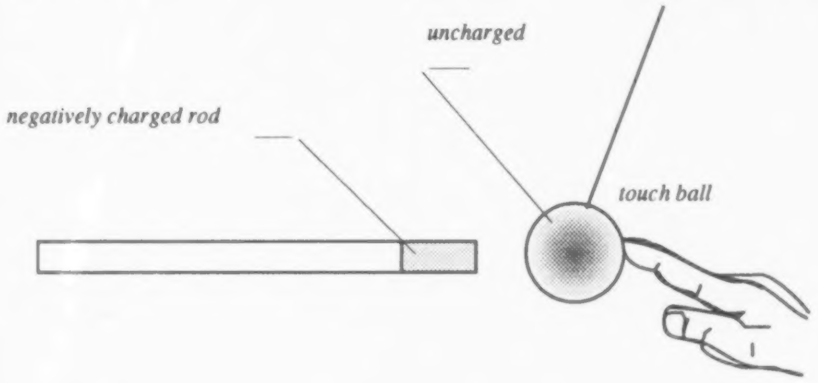
How to explain it:

After rubbing the balloons, they were **charged** with the same charge and since like charges repel, the balloons repelled each other. By spraying water droplets in their vicinity, the water droplets carry the charges away from the balloons, rendering them **neutral**, with the result that they fall against each other.

Another way to neutralize the static charges on the balloons is to touch them with a damp or moist hand. The hand will supply an abundance of negative charges and neutralize the two balloons.

2.4.12. THE INDUCED CHARGE

What you need: 1. A pithball and thread. 2. A plastic rod & fur, or glass rod & silk.


uncharged
negatively charged rod
touch ball

How to do it:

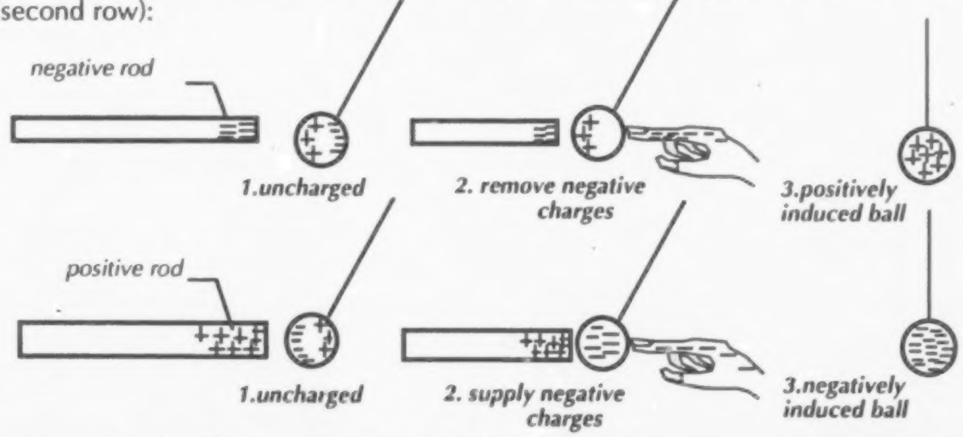
1. Suspend the pithball from a thread.
2. Rub the plastic rod with the fur (or the glass with the silk) to produce negative charges.
3. Approach the pithball with the charged rod (do not touch) with one hand, while touching the other side of the ball with the finger of the other hand (see Sketch above).
4. Remove the finger and then remove the charged rod.
5. Now approach the pithball with a finger: what happens?

What questions to ask:

1. What was the pithball doing when approached by the charged rod?
2. What charges would be induced in the ball by the charged rod?
3. What did the touching with the finger do to the charges on the ball?
4. Why does the finger have to be removed first before the rod?
5. What final charge does the ball have?
6. What final induced charge would the ball have, if it was approached with a positively charged rod?

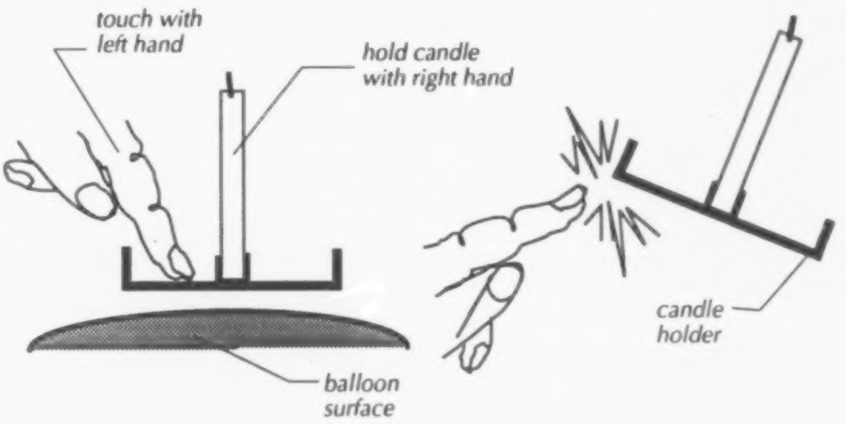
How to explain it:

Here are three steps, each for the induction of the pithball with a negative (first row) and a positive rod (second row):


negative rod
1.uncharged
2. remove negative charges
3.positively induced ball
positive rod
1.uncharged
2. supply negative charges
3.negatively induced ball

2.4.13. THE SPARK-PRODUCING FINGER

What you need: 1. A flat metal candle holder (or dish).
2. A candle (medium size), a large round balloon.
3. A wool or flannel cloth.

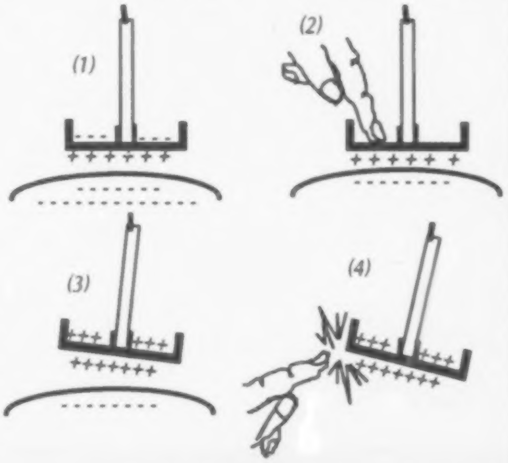


How to do it:

1. Inflate the balloon and rub it vigorously with the wool cloth.
2. Attach the candle to the candle holder, place the candle holder on the rubbed surface of the balloon, using the candle itself as a handle (hold with right hand).
3. Now touch the upper side of the candle holder with a fingertip of the left hand (a small spark may jump to your finger).
4. Lift the candle holder from the balloon, still holding on to the candle with the right hand.
5. Now approach the bottom edge of the candle holder with a fingertip of the left hand (a spark will jump).
6. Steps 2-5 may now be repeated several times.

What questions to ask:

1. Was it actually the finger that produced the spark?
2. Where did the energy originally come from?
3. What type of energy was the original source?
4. What happened when the finger touched the upper side of the holder?
5. What charges jumped from the finger to the holder, when approaching the bottom of the holder?



How to explain it:

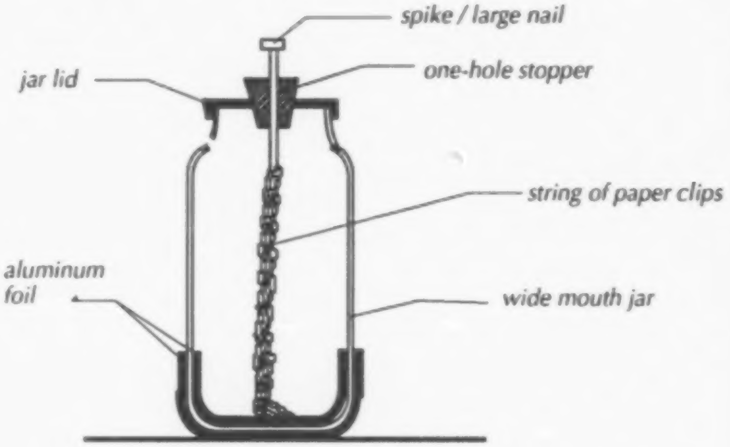
Rubbing the balloon with the wool leaves the balloon negatively charged. Approaching this with the candle holder pushes all negative charges to the upper side of the holder (1). Touching this upper side will remove the negative charges (2), leaving a positive induced charge on the **electrophorus** (3). Negative charges will jump from the finger when brought near the bottom edge of the electrophorus (4).

2.4.14. THE ELECTROSTATIC STORAGE

What you need: 1. A gallon jar (wide mouth) & lid.
2. A spike (10 cm nail) & paper clips.
3. A one-hole stopper, aluminum foil.
4. A plastic rod & wool cloth (or Electrophorus: Event 2.4.12).

How to do it:

1. Make a hole in the jar lid the same size as the one-hole stopper.
2. Cover the bottom to about one-third of the sides up with aluminum foil, on the inside of the gallon jar.
3. Do the same thing with the outside of the jar (see Sketch).
4. Insert the spike in the one-hole stopper and attach a string of paper clips to the end of it, such that the end of the chain will drag on the bottom of the jar.
5. Now insert the stopper in the hole of the jar lid and close off the jar.
6. Charge up the jar with negative static, by rubbing the plastic rod with the wool and touching the spike (or with the electrophorus: Event 2.4.13) and do this about 10 times.



What questions to ask:

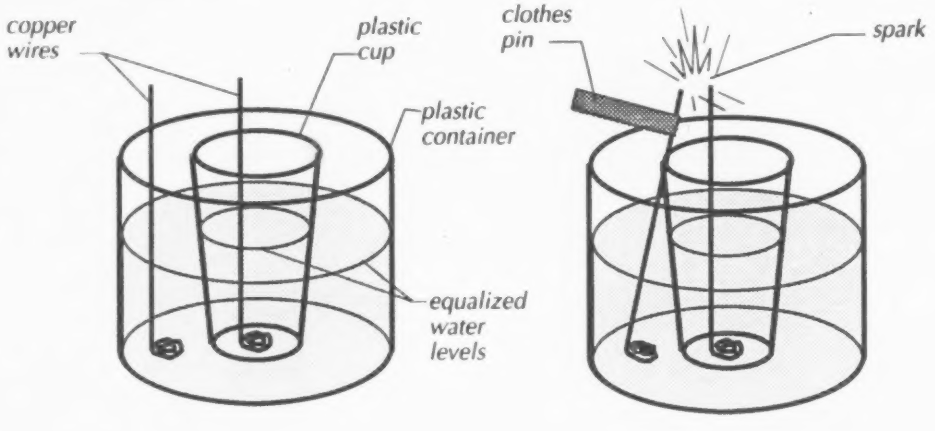
1. What is the purpose of the chain of paper clips?
2. Would the storage jar work without the paper clips?
3. What type of static electricity would we store with the use of the electrophorus from 2.4.12? 4. What would be the danger if we used too small a stopper?

How to explain it:

The two sheets of aluminum foil, separated by the bottom of the jar, act as a **capacitor**. The charges obtained by rubbing the wool over the plastic rod are small charges, which can be **accumulated** in this **Leyden Jar.** The purpose of the paper clips is to connect the inner layer of aluminum foil to the spike. It would be much better if the lid were made of insulating material (material that does not conduct electricity: plastic, hard rubber, etc.). With a metal lid, we must use a rather large rubber stopper in order to prevent charges from jumping from the spike to the lid. With the **electrophorus** (Event 2.4.13) the jar may be charged with 5 or 6 sparks, but with the rod and wool it will take 8-10 times of touching. When the jar is fully charged, we may short the outer foil with the spike with a wire connecting the two, and observe a large spark jump over.

2.4.15. THE WATER CUP SPARK COLLECTOR

What you need: 1. A plastic cup, a plastic container (larger in diameter).
2. Two pieces of bare copper wire.
3. A glass rod & silk or a plastic rod & wool.
4. A plastic or wooden clothes pin.



How to do it:

1. Place the plastic cup in the larger plastic container.
2. Fill the cup 3/4 full with tap water and fill the outer container with water to the same height.
3. Bend the two pieces of copper wire at one end, so that it can stand upright in the containers. Place one in the center and the other in the outer container, immersed in the water.
4. Charge up the capacitor now with the glass rod and silk, or with the plastic rod and wool, by touching the center wire after every rubbing. Repeat this about 10 times.
5. Hold the wire from the outer container with a clothes pin and move the tip closer to the center wire and observe the jumping of the spark!

What questions to ask:

1. How similar is this apparatus to the Electrostatic Storage (4.14)?
2. In which part of the apparatus do the charges collect?
3. What other equipment may be used to charge up the collector?
4. What is the difference in using glass and silk or plastic and wool?
5. What would we need to increase, if we wanted to collect a much larger electrostatic charge?

How to explain it:

This apparatus is very similar to the Leyden Jar (Event 2.4.14). The only difference is, that the collecting surfaces are now, instead of aluminum layers, water layers that are separated by an insulating layer of plastic: the wall of the plastic beaker. Each of the layers is connected with the bare copper wire, and each one has the opposite charge of the other. The glass and silk will produce positive charges in the center, and so will the electrophorus (see Event 2.4.13), whereas the plastic rod and wool cloth will produce negative charges in the center wire.

IMAGINATION IS MORE IMPORTANT

THAN ALL THE FACTS

IN THE WORLD.

- Albert Einstein

SCIENCE INQUIRY
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Science Inquiry Enterprises booth at the NSTA Convention

Can you imagine the science teachers crowding around this booth looking at demonstrations performed by Tik L. Liem, alias Dr. Tickle'm ?

CHAPTER 5

HOW IS CURRENT ELECTRICITY CREATED ?

OBJECTIVES

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

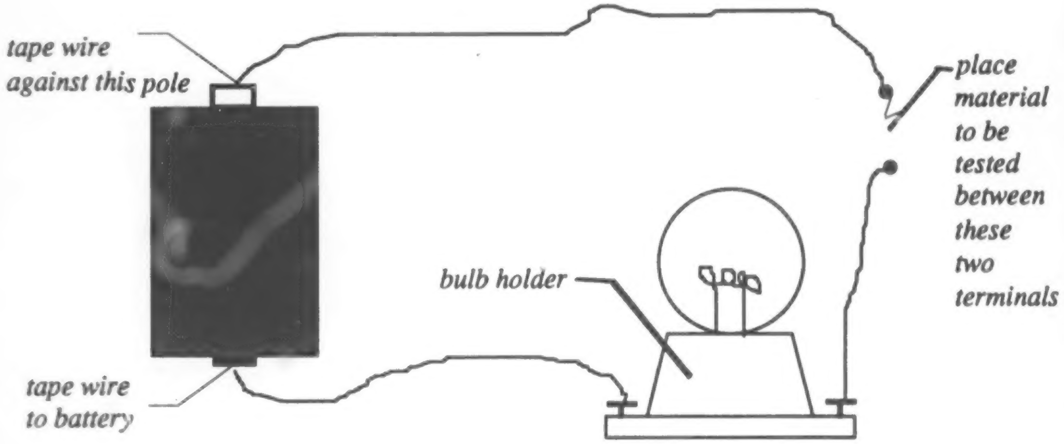
a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

- The conductivity of metals and semi-conductivity of carbon.
- Current electricity can only flow in a completed circuit.
- A circuit may be controlled or broken by switches or fuses.
- Current electricity may be transformed into heat.
- Electricity can be produced from chemical sources.
- A magnetic field exists around a wire which carries electricity.
- A coil of wire can be turned into a strong magnet by electricity.
- Electromagnets have many applications.

2.5.01. MAKE A CONDUCTIVITY TESTER

What you need: 1. A battery (dry cell) and masking tape.
2. A 1.2 volt bulb and bulb holder.
3. Three short wires (bent out paper clips will do).


tape wire against this pole
place material to be tested between these two terminals
bulb holder
tape wire to battery

How to do it:

1. Connect one pole of the bulb holder to the negative pole of the battery (use masking tape).
2. Connect another wire to the other pole of the bulb holder.
3. Tape one end of the third wire to the positive pole of the battery.
4. The two loose ends are the test terminals. Test the light and when the two loose ends are touching each other, the light should go on. (see Sketch)
5. Test any material for conductivity, by placing it between the two loose terminals.

What questions to ask:

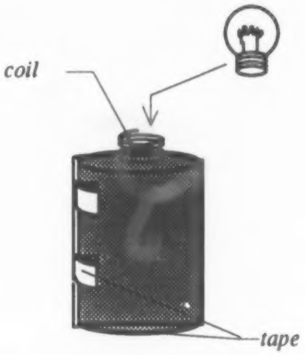
1. What should the light do when a conductor is placed between the two terminals?
2. If both terminals are touching one and the same object, and the light does not go on, what does it mean?
3. Which of the following materials are conductors: a penny, dime, nickel, quarter, aluminum foil, paper, wood, glass, the faucet, watch band, gold ring, ruler, pencil carbon, eraser, etc.?

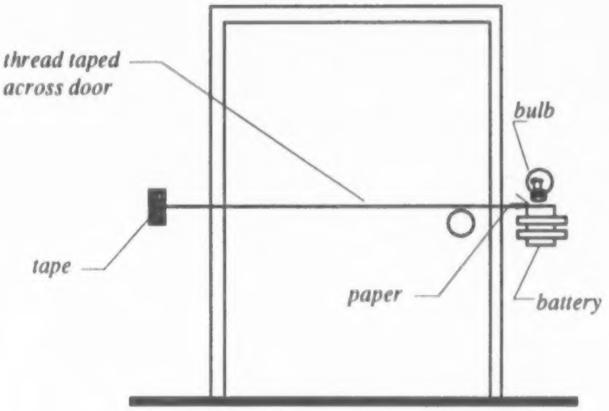
How to explain it:

The difference between **static** and **current** electricity is, that in the former case there is only a build-up of **electric charges**, but no flow of charges except in a spark (a short jump of charges). The latter needs a completed circuit for electrons to flow continuously. In the case of the **conductivity tester**, there is a break in the circuit between the two loose terminals. When a **conductor** is placed between these terminals, the **circuit** is **completed** and the light goes on. When a **non-conductor** is placed between the terminals, the circuit is still broken, because electrons cannot flow through non-conductors, and thus the light stays off. Objects that are made of metal are all electric conductors. Carbon of a pencil is a partial conductor, or semi-conductor.

2.5.02. THE SECRET BURGLAR ALARM

What you need: 1. A battery (dry cell).
2. 1.2 volt bulb and a short solid bare copper wire.
3. Sewing thread and masking tape.





How to do it:

1. Take the copper wire and wind it along the groove of the bulb and bend the wire around the battery and tape the end of the wire against the negative pole of the battery (see Sketch A).
2. Turn the bulb to the right and make sure the bulb lights.
3. Place a piece of paper between the bulb and the battery. (The light should be off. Pull the paper out, and the light should go on.)
4. Tape a thread to the piece of paper (long enough to span across the doorway).
5. Tape the battery plus bulb to one sill of the door and tape the other end of the thread to the other side of the door sill. (Sketch B)

What questions to ask:

1. What should the light do if someone comes in the door?
2. What is preventing the bulb from switching on?
3. What other materials may be used in place of the piece of paper?
4. How is a real burglar alarm triggered?

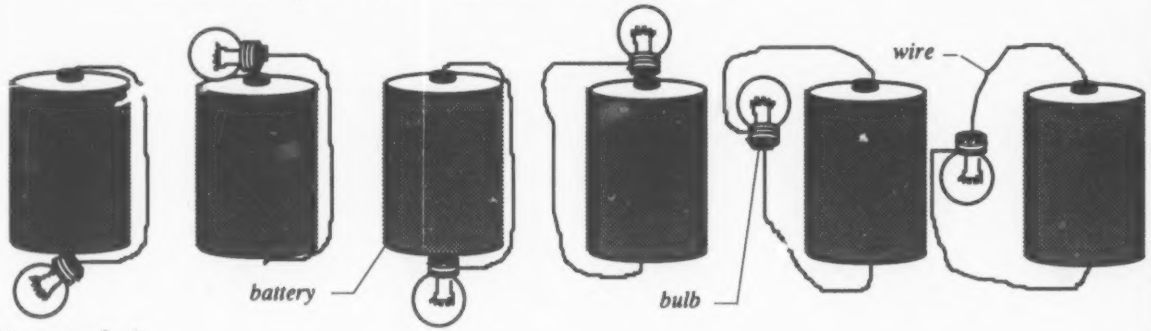
How to explain it:

The function of the paper is to prevent **completion of the circuit**. When the alarm is set the light is not on and when the door is opened or when someone comes in the room the thread and the attached paper is pulled away. This leaves the circuit completed and the light is on. Other materials that may be used to break the circuit are non-conductors like: plastic, cardboard, cloth, or general non-conductors.

A real burglar alarm is triggered by the breaking of a light or laser beam, which is invisible to the human eye, but needed to prevent the completion of the alarm circuit. Breaking of the light beam thus completes the circuit and the alarm sounds.

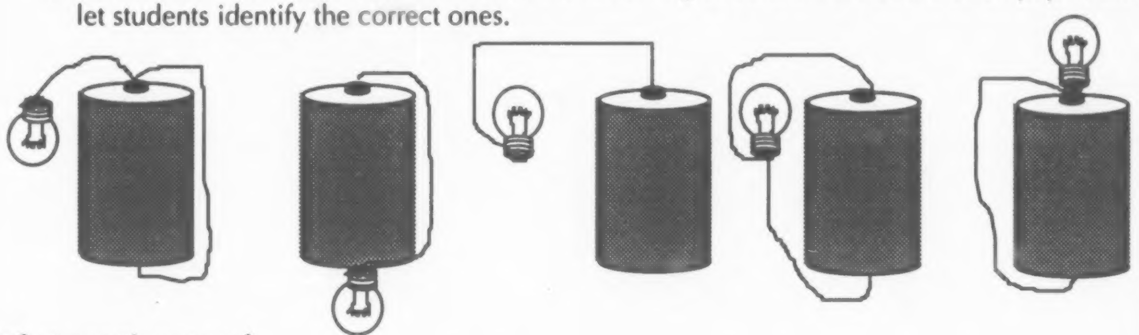
2.5.03. LIGHT THE BULB

What you need: 1. A battery (dry cell) & a small bulb (1.2 V).
2. Two short wires (paper clips or aluminum foil will do).



How to do it:

1. Provide the students with a battery (dry cell), a bulb, and two short wires (or bent out paper clips or aluminum foil strips).
2. Ask the students to light the bulb, with two wires, then with one wire.
3. Ask: "In how many ways can you light the bulb?"
4. Place the above circuits intermixed with the following circuits on the board or on paper, and let students identify the correct ones.

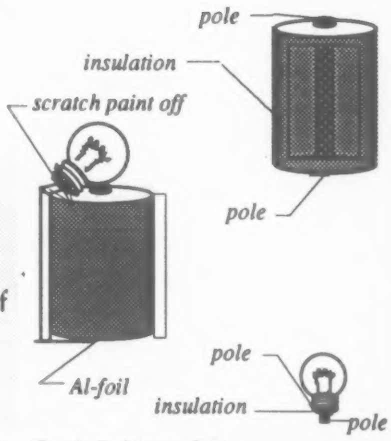


What questions to ask:

1. Will any set-up of the second set of circuits light the bulb?
2. Which of the schematics above are correct to light the bulb?
3. Which two poles of the battery and two poles of the bulb have to be connected to light it?
4. Is it possible to light the bulb without wires or any other materials?
5. What other materials can we use instead of the wires?

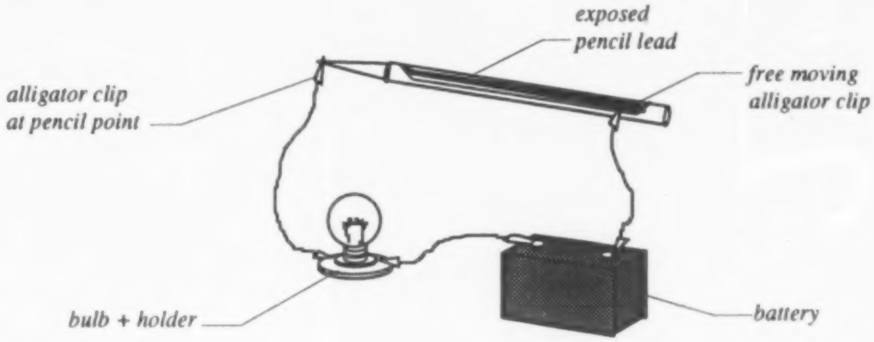
How to explain it:

As long as one pole of the bulb is connected to either + or - of the battery and the other pole of the bulb to the free pole of the battery, the bulb will light. Without wires, the set-up on the right sketch might work, when the insulation of the rim of the battery is scratched off, and the battery is placed on a piece of aluminum foil (some of the bottom rim paint should be scratched off).



2.5.04. REGULATE THE CURRENT WITH A PENCIL

What you need: 1. A long pencil. 2. A 6 Volt battery & 3 alligator clip leads.
3. A bulb (6 V) and bulb holder.



How to do it:

1. Cut the wood of the pencil away to expose the lead.
2. Connect the three wire leads with the alligator clips as follows: **a.** From the pencil point to one pole of the light bulb. **b**. From the other pole of the light to one terminal of the battery. **c.** From the other terminal of the battery to the open exposed pencil lead (free moving end of the wire).
3. Hold the free end of the third wire lead and slide the alligator clip over the exposed pencil lead. Observe the light bulb!

What questions to ask:

1. Is pencil lead a conductor of current electricity?
2. Why did the light bulb glow dimmer and brighter?
3. What did we have to do in order to make the bulb glow dimmer?
4. Do you think there is more or less resistance for the current to flow through pencil lead compared to copper wire?

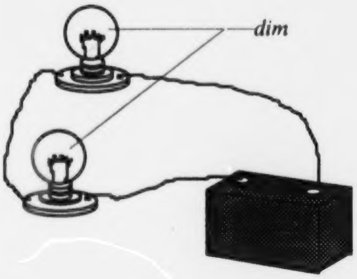
How to explain it:

Pencil lead is a **semi-conductor** of **current electricity.** This means that not all the electrons can flow through, thus the **voltage** is hereby reduced. The longer the length of the pencil lead is in the circuit, the more the **resistance** for the electrons to flow through, and so the lower the voltage, with the result that the bulb is glowing dimmer. By sliding the free end of the wire closer to the stationary end of the pencil(point), this resistance gets less and thus it gets easier for the electrons to flow, resulting in a brighter glow of the bulb.

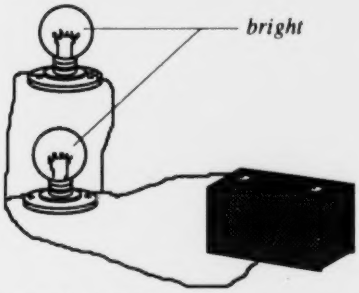
A very long metal wire will have the same effect as the short pencil lead. A **variable resistance**—a resistance that can be changed at will—is called a **rheostat.** Rheostats are applied in dimmer switches, stove and oven temperature controls, and other appliances requiring current flow regulators.

2.5.05. THE DIMMER AND BRIGHTER BULBS

What you need: 1. A battery (dry cell) and holder.
2. Two 1.2 Volt bulbs and bulb holders. 3. Four lengths of copper wire.



Sketch A: Series Circuit



Sketch B: Parallel Circuit

How to do it:

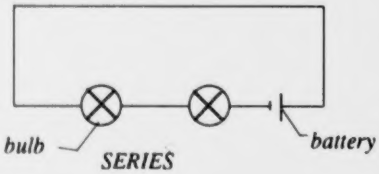
1. Take a battery in its holder and two bulbs in their holders and connect them as pictured in Sketch A.
2. Turn one of the bulbs loose in the socket (both bulbs go off).
3. Change the circuit and connect the wires as pictured in Sketch B (the bulbs burn with a brighter light).
4. Now turn one of the bulbs loose in its socket (only this one bulb turns off and the other stays on).

What questions to ask:

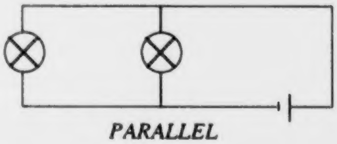
1. Why are the bulbs in the first circuit glowing dimly?
2. Why are the bulbs in the second circuit glowing brightly?
3. What is the reason that both bulbs are turned off when only one is turned loose in its socket in the first circuit?
4. Why does the second bulb stay on in the second circuit, when one bulb is turned off?
5. What type of circuit would we have in our home?

How to explain it:

A glowing bulb in an electric circuit gives a certain resistance to the electron flow in the circuit. In the **series** circuit, the bulbs follow one after another in one wire, adding to the resistance in the current flow, and thus dimming the glow of the bulb. In the **parallel** circuit this is not the case. Each bulb is individually connected to the battery, independent from each other. This is the wiring system used in our homes. An example of a **series** and **parallel** circuit is found in the Christmas lights. Those with one wire in between the bulbs are wired in series, whereas those with two wires in between the bulbs have a parallel circuit.



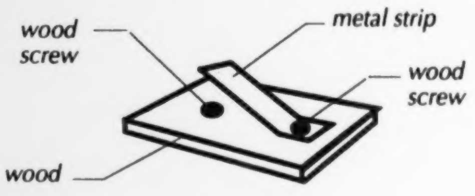
SERIES



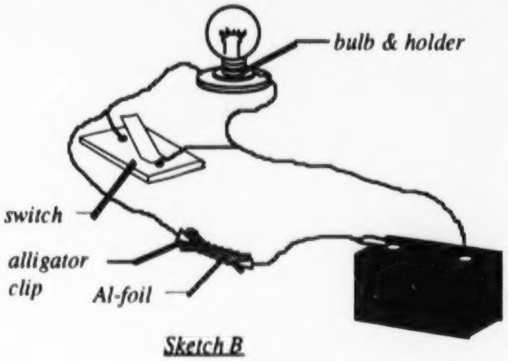
PARALLEL

2.5.06. THE ALUMINUM FOIL FUSE

What you need: 1. A strong battery (6V) or five 1.2 V batteries.
2. Copper wire and aluminum foil. 3. Bulb (6V) and holder, and simple switch.



Sketch A : Simple Switch



Sketch B

How to do it:

1. Cut a piece of aluminum foil (a gum wrapper will do) in the shape illustrated in the circuit of Sketch B.
2. Make a simple switch from a piece of wood, a metal strip (or paper clip) and two small wood screws (Sketch A).
3. Connect the aluminum foil fuse, the switch and the light bulb to the battery in a circuit pictured in Sketch B (when the switch is open, the bulb should be on).
4. Now draw students' attention to the light and the fuse: push the switch closed; the fuse blows and the light goes out (even when the switch is released, the light stays out).

What questions to ask:

1. Why does the fuse not blow when the switch is left open?
2. Why does the fuse blow when the switch is closed?
3. What does the switch actually do to the circuit when it is closed?
4. What is the purpose of a fuse in an electrical circuit?

How to explain it:

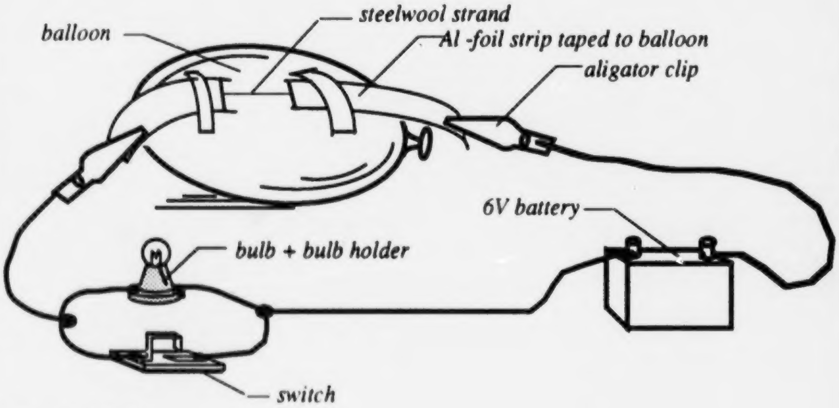
The switch in this circuit has the purpose to **short the circuit**. When the switch is closed, the current from the battery can flow much faster, because it does not have to pass the bulb. Electric current, just like a flow of water through pipes, seeks the **path of lowest resistance.** When there are two paths of which one has a higher resistance, the current will flow through the one with the lowest resistance: in this case the closed switch rather than the bulb. The sudden stronger current makes the thin aluminum foil too hot to stay whole and burns off. When the switch is now released, the circuit stays broken, because of the broken fuse, and thus the light stays off until the fuse is restored.

The purpose of a fuse is to prevent the start of a fire in case of a **short circuit.** This latter can heat the wires so much that the insulation might catch fire. A fuse will break the circuit immediately when shorted.

2.5.07. THE BALLOON FUSE

What you need: 1. A small balloon, aluminum foil, simple switch.
2. A strong battery (6V) or five 1.2 V D-batteries.
3. Bulb (6V), bulb holder, copper wire, steelwool.

How to do it:



1. Cut two strips of aluminum foil and tape one strand of steelwool between the two strips against the balloon (see Sketch).
2. Use the copper wire to complete the circuit as laid out in the Sketch. (same circuit as in Event 10.6)
3. Show students that the light is burning because the circuit is complete.
4. Draw their attention now to the switch, which will make the short circuit when closed, and the single strand of steelwool on top of the balloon.
5. Insist on everybody's attention, then push the switch: BANG! The fuse broke and the light is off!

What questions to ask:

1. What made the balloon pop when the switch was pushed?
2. What is a short circuit?
3. Which way would electricity rather flow, through the switch or the bulb?
4. Why did the light go out after the balloon popped?

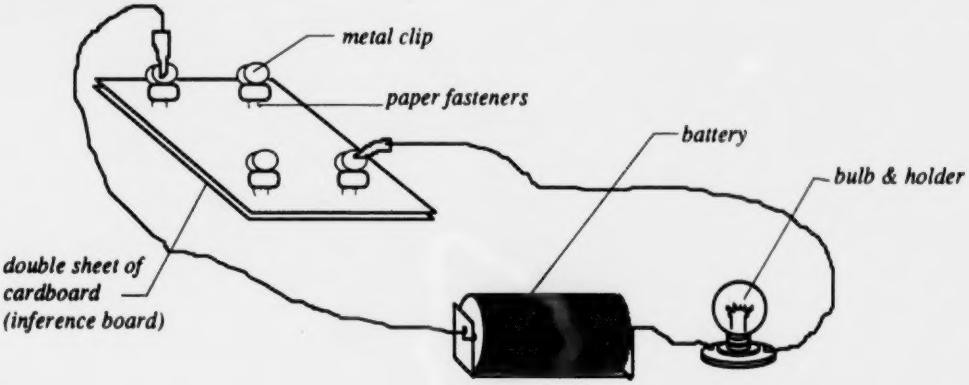
How to explain it:

The single strand of steelwool had the function of the **fuse** wire. When the circuit was **shorted** by pushing the switch, a sudden surge of electric current was flowing through the circuit causing the single strand of steelwool to heat up. As this strand of steelwool was taped against the balloon, it melted the rubber and bursted it. With the steelwool strand broken, the **circuit** in which the bulb is wired is thus **incomplete**, and so the light stays out.

In our daily life, in most electrical appliances, all automobiles and homes are protected with fuses. These fuses can let a certain amount of electricity pass through (f.i. 10, 15, or 20 amperes). When a sudden surge of electrical flow occurs the fuse breaks. In the new homes they are called **circuit breakers** which click off when a short circuit occurs and can be reset after the short is repaired.

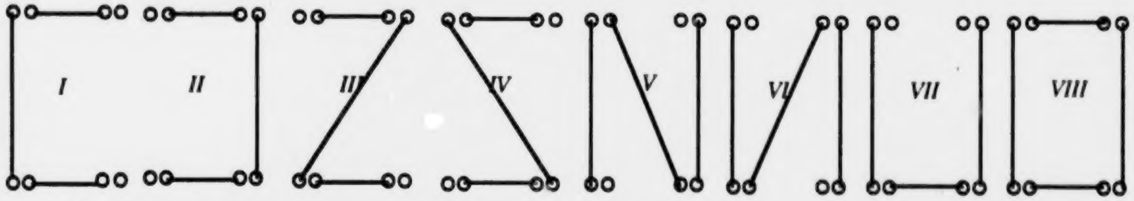
2.5.08. THE INFERENCE BOARDS

What you need: 1. Cardboard sheets (15 x 20cm), paper fasteners.
2. Metal clips (large), copper wire (bare), masking tape.
3. Light bulb & holder, battery & holder.
4. Wire leads with alligator clips.



How to do it:

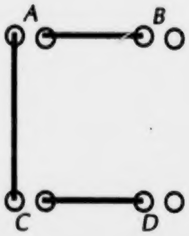
1. Make 4 to 8 different inference boards, by pushing paper fasteners through the cardboard sheets, bending the two prongs, connecting the fasteners with the bare copper wire (Sketch below), covering the back with another cardboard sheet (tape together) and placing the metal clips over each pair of paper fasteners. The 8 patterns are as follows:



2. Connect the bulb and battery with the wire leads as in the sketch above and clamp two terminals with the alligator clips (f.i. B & C), take clip A or D (one at a time) off the paper fasteners, and infer the wire pattern from the light bulb's off or on observations.

What questions to ask:

1. When the alligator clips are connected to terminal B and C, and the light is on, what would be your inference?
2. With alligator clips on B and C, light on, taking off metal clip A, and the light goes off, what would be your inference now?



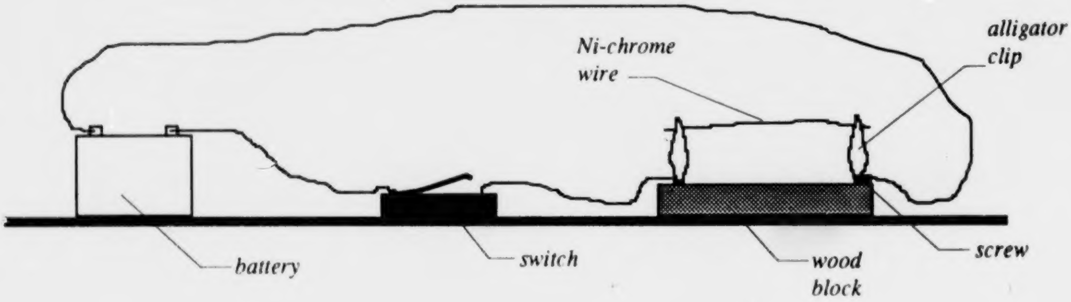
How to explain it:

With the alligator clips of the testing instrument on B and C, the light will go on, because the current will pass through A. But as soon as the clip A is taken off, the light will go off. Taking off clip D will not affect the burning light bulb.

The connections behind the cardboard should be soldered.

2.5.09. CHANGE ELECTRICITY INTO HEAT

What you need: 1. Nickel-chrome wire and alligator clips stand.
2. A battery (6V), 3 wires, a simple switch.



How to do it:

1. Connect the wires in the circuit as outlined in the sketch.
2. Clip the Ni-chrome wire between the alligator clips, making sure that they make connection (by doubling or tripling the wire where it is clipped).
3. Push the switch to complete the circuit and observe the Ni-chrome wire.
4. Show that the wire is actually red hot by touching a piece of paper to the Ni-chrome wire, while keeping the circuit closed.

What questions to ask:

1. What is the original source of energy?
2. What is the electricity changed into?
3. What would a thin copper wire do in place of the Ni-chrome wire?
4. Where do we find an application of this principle?
5. What made the electricity change into heat?

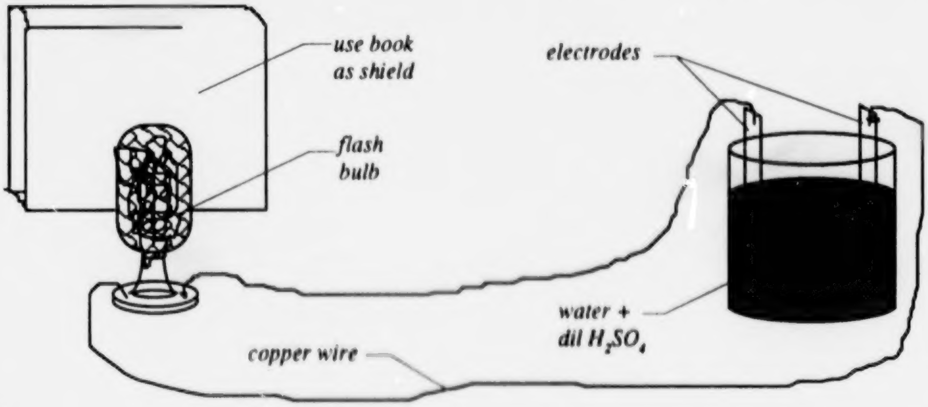
How to explain it:

The 6 Volt battery is the original **chemical source of energy**, which is turned into electrical current. It passes through the Ni-chrome wire and is transferred into heat at that spot. The flow of electrons through the Ni-chrome wire may be compared to the flow of water through a narrow pipe. The current is flowing without resistance through the rest of the circuit, but in the Ni-chrome wire, the flow is hampered because of the small size of the wire (in diameter). The **flow of electrons** in this part of the circuit creates **friction** between the electrons and the wire molecules, resulting in the formation of heat.

As the melting point of Ni-chrome is much higher than copper, the wire can glow without melting, but if a fine copper wire were used in its place, it would melt and break the circuit as a fuse would. This change of electric energy into heat is applied in electric stoves, ovens, toasters, heaters, dryers, kettles, etc.

2.5.10. THE LIQUID BATTERY

What you need: 1. A copper and a zinc (or magnesium) strip.
2. Dilute sulfuric acid, copper wire leads. 3. A beaker, a flash bulb & holder (or 0.2 V bulb).



How to do it:

1. Fill the beaker half full with water and add dilute sulfuric acid till the beaker is 3/4 full.
2. Make small nail holes in one end of each of the electrodes and connect the copper wires from each of the electrodes to the two terminals of the bulb holder (**do not** dip the electrodes in the beaker yet!).
3. Stand a book in front of the flash bulb (to prevent students from getting blinded by the flash of light).
4. Hold the two electrodes, one in each hand, let students observe, and immerse the electrodes quickly in the liquid. (The electrodes should be gleaming clean: scraping with sand paper may help.)

What questions to ask:

1. What made the flash bulb light?
2. What materials made up the source of the electric current?
3. Why was a shield necessary between the bulb and the observer?
4. What triggers the flash in a camera flash?

How to explain it:

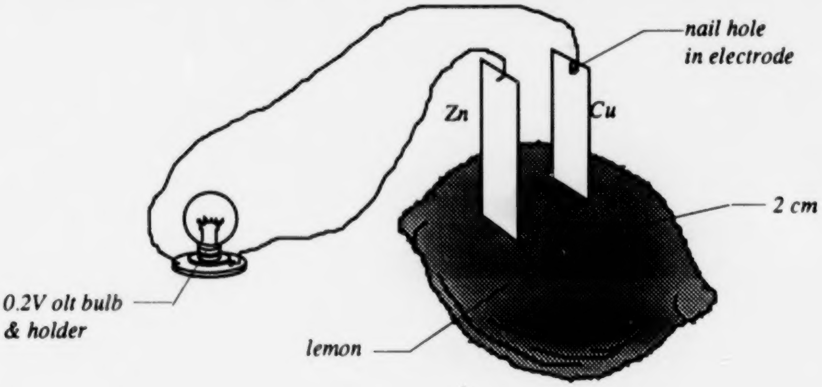
This battery is normally called a **wet cell,** because liquid is involved. Car batteries are usually wet cells: sulfuric acid and water acting as the **electrolyte** and lead (and lead oxide) as the **electrodes.** In this case the copper and zinc strips were the electrodes. Zinc (or magnesium) having more of a tendency to lose electrons compared to the copper, acts together with the H_2SO_4 electrolyte as the source of electron flow.

Without the book as a shield, students might get temporarily blinded by the bright flash, especially when they look directly at the bulb. It is a good precaution to use a shield, as the flash is bright enough to be seen without directly looking at the bulb. When using a regular small bulb, this shielding is not necessary.

The flash of a camera flash is triggered by the built-in battery, either in the camera, the flash holder, or the flash cube itself.

2.5.11. ELECTRICITY FROM A LEMON

What you need: 1. A copper and a zinc strip (electrodes).
2. Two copper wire leads. 3. A galvanometer or a 0.2 Volt bulb.



How to do it:
1. Make a small nail hole in the end of the metal strip.
2. Insert the copper and zinc strip into the lemon vertically, about 2 cm apart from each other.
3. Connect the wire leads to each of the electrodes and connect one of the other ends to one terminal of the bulb holder.
4. Get ready with the other loose end of the wire to touch the open terminal of the bulb holder. Before touching it, draw students' attention to the bulb (or galvanometer).
5. Touch the terminal with the loose end of the wire for short moments at a time (the current is so weak that you will not get electrocuted!)

What questions to ask:
1. Where does the current come from?
2. What is current electricity actually?
3. Can we use other metals to make electricity with the lemon?
4. Would two strips of the same metal produce electricity?
5. What other fruit can be used instead of the lemon?

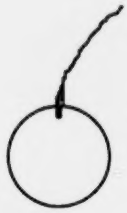
How to explain it:

Current electricity is a **flow of electrons** through a completed circuit of conductors. The **source** of the electron flow in this case is the combination of copper and zinc strips in the citric acid of the lemon. Zinc has more of a **tendency to lose electrons** compared to copper, and thus connected through the wires and light bulb, the electrons flow from the zinc to the copper strip.

Other metal pairs that could be used to develop **potential differences** or **electromotive forces** (EMF), are: copper and silver, copper and iron, copper and magnesium, etc. Other fruit that could replace the lemon are: orange, grape fruit; less potential difference comes from apple, pear and peach. It is the acidity (the citric acid) in the fruit, which is necessary to conduct the electrons from one electrode to the other.

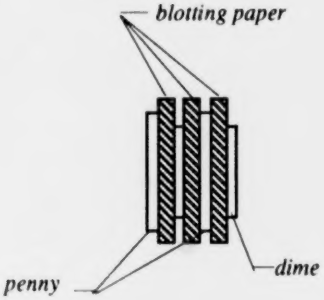
2.5.12. THE COIN BATTERY

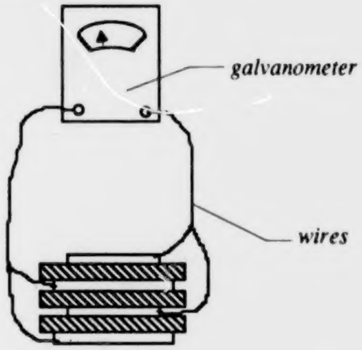
What you need: 1. Two pennies and two dimes. 2. Blotting paper or thick paper towel. 3. Copper wire and a galvanometer. 4. Common table salt.



Sketch A

Sketch B





Sketch C

How to do it:

1. Clean the coins thoroughly with a brush, soap and water until gleaming.
2. Punch a nail hole close to the edge of the four coins, and attach a short and a longer copper wire to the two pennies, and do the same to the two dimes (see Sketch A).
3. Soak pieces of blotting paper in salt water and arrange the pennies and dimes between the blotting paper as in Sketch B.
4. Attach the wires to the galvanometer like in Sketch C. Before completing the circuit, draw students' attention to the galvanometer needle, then touch the terminal with the loose wire. (You will not feel any electric shock, as the currents are just very weak ones.)

What questions to ask:

1. Why do the coins have to be cleaned?
2. Where does the electricity come from?
3. What is the source of the electron flow?
4. What is the function of the salt water?
5. Would using more pennies and dimes increase the current?

How to explain it:

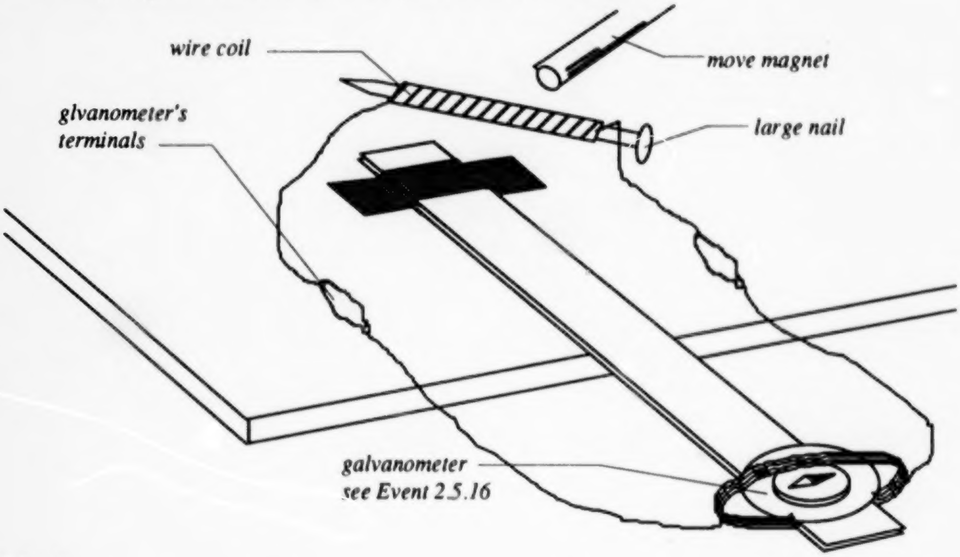
The dime and the penny act as silver and copper electrodes. The salt water in the blotting paper is the **electrolyte** needed to get a transfer of electrons from the silver to the copper. In this case, copper has a greater **tendency to lose electrons** than silver, and a flow of electrons is created from the copper to the silver electrode when the circuit is completed. The sodium (Na^+) and chloride (Cl^-) ions are the electron carriers in the electrolyte. Without the salt, the electrons cannot flow and thus no current is produced.

The larger the surface of the electrodes, the larger the **potential difference** between the electrodes. The increase in the number of pairs of coins would therefore increase the voltage as well as the current (amperage).

The common dry cell uses carbon and zinc as electrodes, with damp ammonium chloride (NH_4Cl) as electrolyte.

2.5.13. ELECTRICITY FROM A COIL ?

What you need: 1. Bell wire, a large nail, a strong magnet.
2. A simple galvanometer (or compass and coil of wire).



How to do it:

1. Wrap the bell wire around a large nail (or steel bolt) with at least 20 windings to make the coil.
2. Attach the ends of the coil to the terminals of the galvanometer (the simple galvanometer of Event 5.15 may be used).
3. Now take the strong magnet and move one pole of it back and forth near the coil, while observing the needle of the galvanometer.
4. Turn the rod magnet end for end and move the other pole back and forth near the coil. What does the galvanometer show?

What questions to ask:

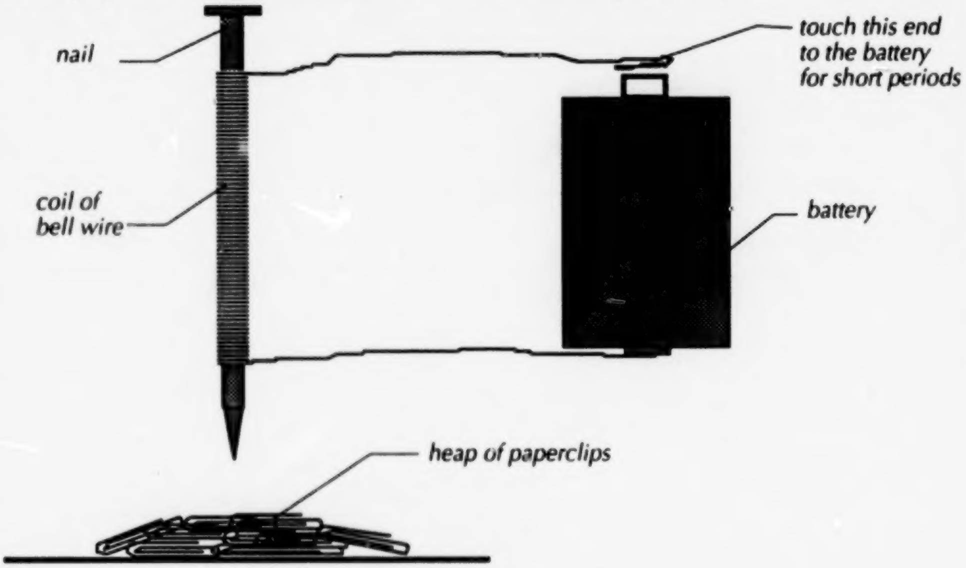
1. After reversing the magnet, what happens to the galvanometer?
2. What is the source of energy that is converted to electricity?
3. What factors are influencing the increase of the current output?
4. Where do we find this principle applied in daily life or industry?

How to explain it:

This is an example of an **electromotive source of electricity,** where mechanical energy is converted into electrical energy. By moving the pole of the rod magnet back and forth near the coil, an electric current is produced in the coil, which is detected by the galvanometer (an instrument to detect weak currents). By moving the magnet in one direction along the coil and then back again, we can see that the deflection of the galvanometer needle changes direction, meaning that the current **alternates** from one direction into the other. The electrical generators in power plants are based on the same principle, where coils are moving in a strong magnetic field to produce **alternating current (AC).** The bicycle dynamo is an example of a generator that produces **direct current (DC).**

2.5.14. THE NAIL MAGNET

What you need: 1. A large nail (10 cm long), bell wire (1 m long).
2. A 6 V battery (or 3 1.2 V D-size batteries). 3. A box of paper clips.



How to do it:

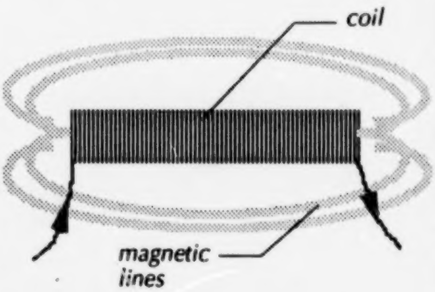
1. Wind the bell wire around the nail (about fifty times).
2. Scrape the insulation off from the ends of the wire and place the paper clips in a heap on the table.
3. Have someone hold the nail above the heap of paper clips , touch the two ends of the wire to the battery poles and let the student raise the nail. How many paper clips were picked up?
4. Wind another ten loops of the wire around the nail and complete the circuit again. Have the students count the number of clips picked up.
5. Increase the number of batteries (by placing them in series and connecting + pole to - pole of the next battery). Have students count the number of paper clips picked up.

What questions to ask:

1. What made the coil become a magnet?
2. What effect did increasing the number of windings have on the magnetic attraction force of the nail?
3. What did two or three batteries in series do to the magnetic force?
4. Would removing the iron core of the coil weaken or strengthen the magnetic attraction?
5. How does the magnetic attraction of the coil change when the core is changed into a wooden, glass, or other kind of rod?

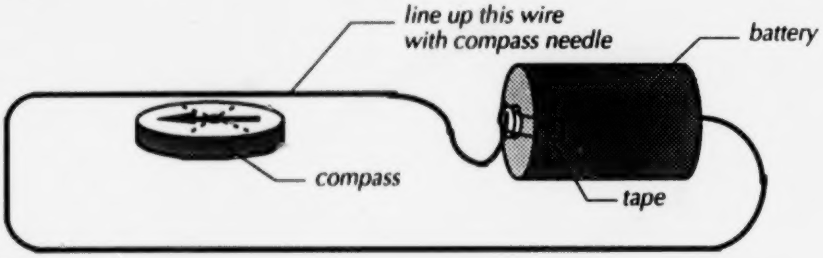
How to explain it:

When an electric current flows through a coil, it acts as a magnet. By placing an iron rod inside the coil, the magnetic lines pass through the iron rod and the coil becomes a much stronger magnet, as long as the electric current flows through the coil. The more windings in the coil, the stronger the magnetic force. This force is also directly proportional to the magnitude of current.



2.5.15. THE DEFLECTING COMPASS

What you need: 1. A D-size battery (1.2 V). 2. Copper bell wire (and a simple switch).
3. A magnetic compass.



How to do it:

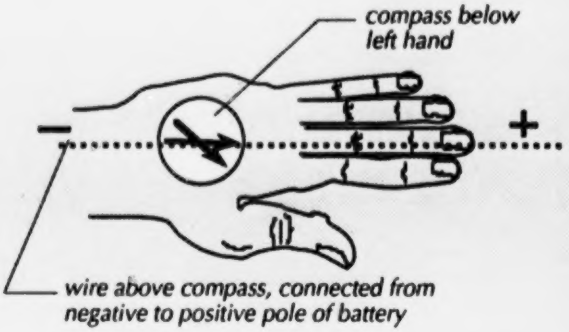
1. Distribute one compass, one battery and a length of bell wire to the students.
2. Instruct them to do the following:
   - a. Line up one wire coming from the positive pole of the battery with the compass needle by holding it above the compass (tape the wire end to the battery).
   - b. Bring the other end of the wire to the negative pole of the battery but do not complete the circuit yet (use a switch if available).
   - c. Pay attention to the compass needle, touch the battery with the loose end of the wire for short periods.
   - d. Place the compass above the wire, complete the circuit, what happens?

What questions to ask:

1. What did the compass needle do when the circuit was completed?
2. How did the compass needle deflect when it was above or under the wire?
3. What is the reason for the compass needle to move?
4. What would the compass needle do if we would approach it with a magnet?
5. What can we conclude about the surroundings of an electric current?

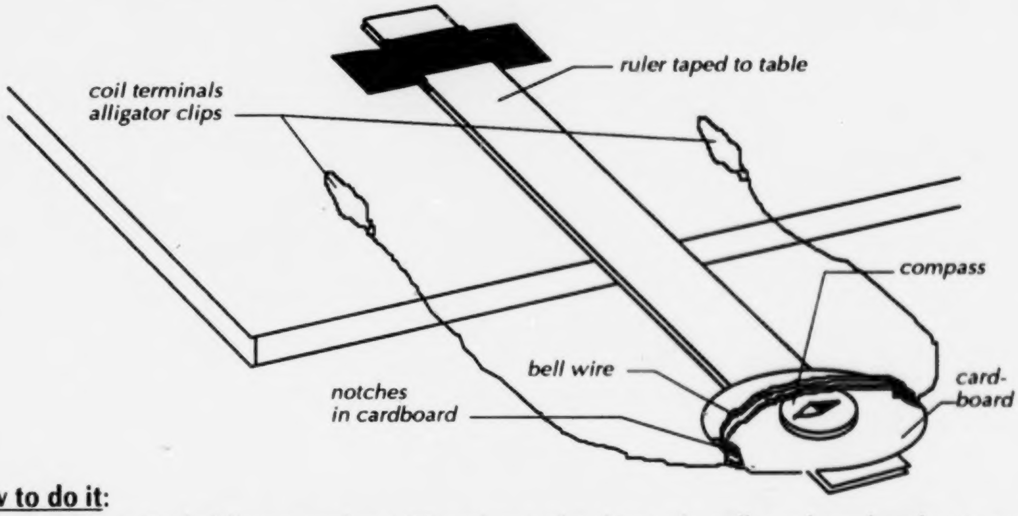
How to explain it:

This demonstration shows that a **magnetic field** exists around an electric current. As soon as the circuit is completed, by touching the loose end of the wire to the battery, the North-pointing needle of the compass will deflect to the left (the way it is set up in the sketch). The left hand rule may be discovered by the students: When holding the left hand over a compass, such that the flow of electrons is from the wrist to the fingertips, the North-pointing needle deflects along the opening thumb. (Make sure that the palm is facing the compass.)


compass below
left hand
−
+
wire above compass, connected from
negative to positive pole of battery

2.5.16. THE SIMPLE GALVANOMETER

What you need: 1. A small compass (magnetic), bell wire, two alligator clips.
2. Cardboard, plastic ruler (30 cm) and masking tape.



How to do it:

1. Cut out a circle (diameter about 10 cm) out of a sheet of cardboard, and make two notches opposite to each other.
2. Wind the bell wire in a coil of at least 10 windings, with the same ,diameter (10 cm) and fit it in the two notches perpendicular to the cardboard circle.
3. Tape a ruler to the table top and tape the cardboard with the coil to the protruding end of the ruler (see Sketch).
4. Connect alligator clips to the two ends of the coil and leave this on the table top.
5. Tape the small compass in the center of the cardboard and line up the needle with the coil (by moving the ruler in a N-S direction)).
6. You are now ready to test the galvanometer: any small current through the coil will move the compass needle.

What questions to ask:

1. What makes a compass needle move in general?
2. What does the coil turn into when current passes through it?
3. What will make the galvanometer more sensitive?
4. What does a galvanometer measure?

How to explain it:

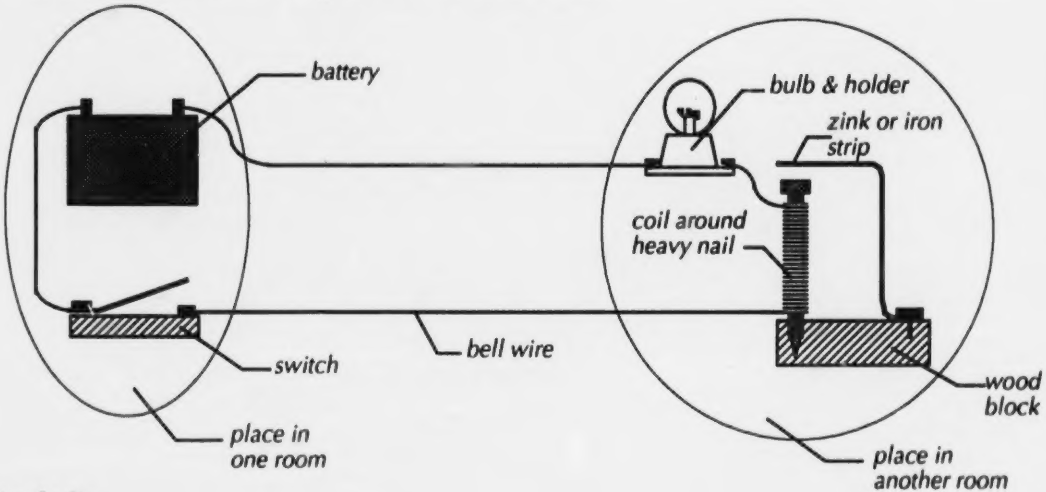
When an electric current is led through a **coil**, the latter is turned into a **magnet**. A magnetic field is thus created around the compass, when a small current passes through the coil, and this field deflects the compass needle. The more windings in the coil, the stronger the magnetic field and thus the more sensitive the instrument.

The stronger the current passing through the coil, the stronger the magnetic field created around the coil and the more the compass needle will deflect. A large deflection therefore indicates a larger current. When the current is passed in the opposite direction through the coil, the magnetic poles switch and the compass needle deflects in the opposite direction. The instrument therefore, not only measures the strength but also the direction of weak currents.

2.5.17. THE SIMPLE TELEGRAPH

What you need: 1. A simple switch, nail and bell wire.

2. A battery (6 V) and bulb (and holder).
3. A small block of wood, strip of tin, and small screw.



How to do it:

1. Hammer the nail 1/4 way into the block of wood, wind about 20-30 loops around the nail, and further connect the bell wire to the bulb, battery, and switch (see circuit in the sketch).
2. Bend the tin strip (cut from a tin can) in an S-form and screw it to the other end of the wood block, such that a small gap is left between the strip and the nail head (see Sketch).
3. Push on the simple switch for short periods of time to close the circuit and observe the light go on and the metal strip move down.

What questions to ask:

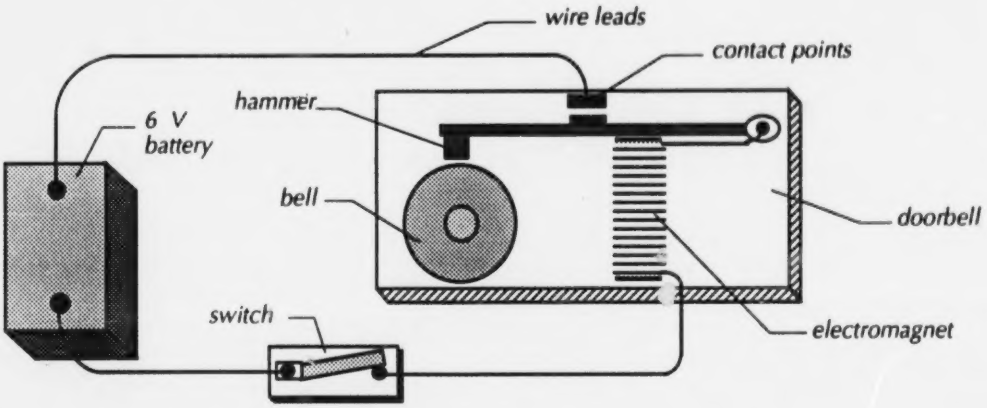
1. What made the metal strip bend down towards the nail?
2. Would the metal strip still be dipping down, even when this 'nail switch' and light are several km away from the simple switch?
3. What does the light suggest about the circuit, when it is on?
4. Does the light bulb have to be part of the circuit in order for the metal strip to be attracted to the nail?

How to explain it:

The closing of the simple switch completes the circuit, resulting in a flow of electrons through the coil of wire around the nail. This produces a **magnetic field** around the coil as the coil turns into a magnet, attracting the metal strip down towards the nail head. The completed circuit also makes the light go on. Without the light in the circuit, the metal strip still bends down towards the nail when the simple switch is pushed down. The completed circuit also makes the light go on. Whenever the simple switch is released, the circuit is broken, and the coil stops acting as a magnet, resulting in the release of the metal strip. As the strip has some spring action properties, it springs back up, as soon as the attraction forces disappear. This is the principle of the **telegraph,** where **Morse codes** are sent over long distances. Ships at sea communicate by Morse codes in terms of long and short flashes of light.

2.5.18. TURN ELECTRICITY INTO SOUND

What you need: 1. A simple doorbell and switch.
2. Two wire leads and a dry cell (6V).



How to do it:

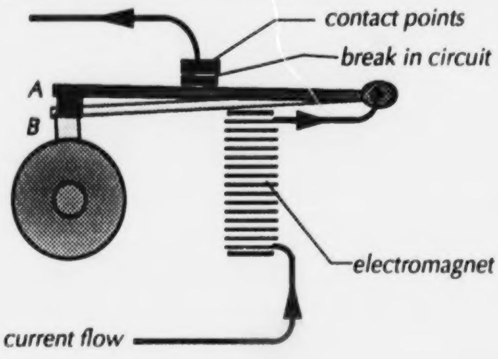
1. Take the cover off the doorbell and expose the electromagnet, bell, hammer and contact points.
2. Connect one wire to one terminal of the simple switch, and the other wire with a wire lead (with alligator clips) to the dry cell.
3. Attach the other wire lead between the simple switch and the free pole of the battery (circuit is pictured in Sketch).
4. Complete the circuit now by pushing the simple switch.

What questions to ask:

1. What is accomplished in the circuit by holding down the simple switch?
2. As soon as electricity runs through the coil, what does it become?
3. What will the hammer do to the circuit when it hits the bell?
4. Why does the hammer move back towards the contact point?

How to explain it:

When the simple switch is pushed down, the **circuit is completed**, and electricity flows through the coil. This turns the coil into a magnet, pulling the hammer towards it and in doing so it hits the bell. In the **B** position (see sketch on right) against the bell, the hammer actually breaks the circuit and the coil does not attract the hammer any more; thus it flips back towards the contact point, resulting in closing the circuit again, and the whole cycle starts over. This on and off switching of the circuit happens very rapidly in succession and a vibration of the hammer results.



When we are confronted with something unusual,
a DISSONANCE is created in our mind
which is uncomfortable.

We, therefore, are motivated to find a CONSONANCE
to replace the DISSONANCE.

- Leon Festinger

A CONSONANCE = AN EXPLANATION

Can we actually make a CLOUD IN A BOTTLE ?

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CHAPTER 6

HOW DOES LIGHT BEHAVE ?

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

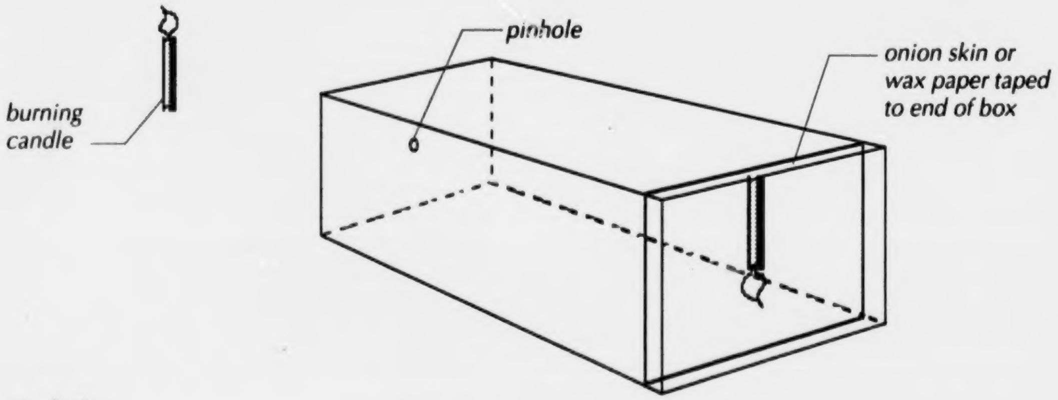
a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
b. Explain in their own words which of the sub-concepts is determining the course of an event;
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

— Light travels in straight lines.
— The image of an object is seen exactly the same distance behind the mirror as the object is in front of it.
— The angle of incidence is the same as the angle of reflection.
— Light is refracted towards the normal when coming from a less dense medium into a denser medium.
— When the critical angle is exceeded, the border between two different media will act as a mirror.
— Real images may be formed by holding a lens between a light source and a paper card.
— White light is scattered into a spectrum of rainbow colors when passed through a prism of denser material.

2.6.01. MAKE A PINHOLE CAMERA

What you need: 1. A shoe box and onion skin paper (thin paper). 2. A candle.



How to do it:

1. Take the shoe box and cut out the side of one end of the box and tape the thin onion skin paper to it.
2. Make a small round hole in the other end of the box and tape the lid to the box. (Make the hole a little larger than a pin hole).
3. Point the hole-end of the box towards a window or a light- source: lamp or candle, and observe the image on the thin paper (prevent light from falling on the outside of the onion skin paper.

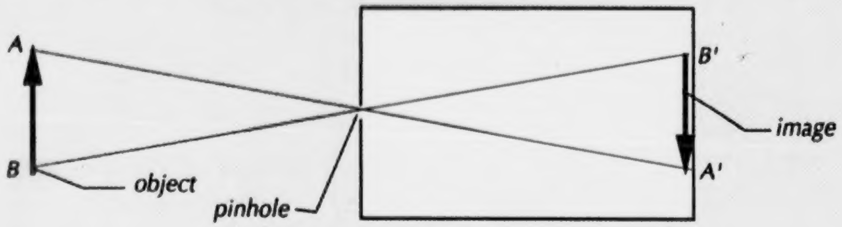
What to ask:

1. What do you observe on the onion skin paper ?
2. Why is the image on the paper always upside down?
3. What would happen to the image if the pinhole were enlarged?
4. How do the light rays travel from the object to the image?

How to explain it:

Light travels in **straight lines**. This is why the image is always inverted. The light from point A of the object travels in a straight line through the pinhole to point A′ on the onion skin of the box, and from point B to Point B′ thus inverting the image. When the pin hole is enlarged the image will get blurred. The smaller the hole (aperture in a camera), the sharper the image.

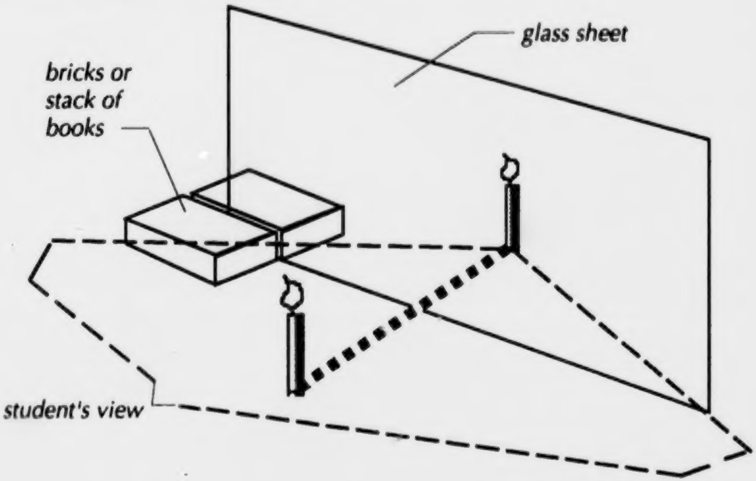
The onion skin paper at the end of the box may be replaced with a photographic plate and exposed for a short time. (The box has to be held steady.)



2.6.02. THE COOL CANDLE FLAME

What you need: 1. A rectangular piece of window glass.
2. Two identical candles (same height, diameter).

How to do it:



1. Mount the glass sheet vertically between four bricks or four stacks of books. (Or hold it in two mounts of molding clay).
2. Fix one candle in front of the glass sheet on the table (10 cm measured on the perpendicular to the glass).
3. Fix the second candle in the back of the glass sheet on the table (exactly the same distance from the glass). Block the student's view of the first candle with a large book or folder, and light **only** this candle (do as if you light both candles), then remove the folder. (Student's should sit in places, such that they cannot see the second candle without looking through the glass sheet—students' view, in sketch).
4. Place your (or a student's hand) above the second (unlit) candle for a very short while and withdraw. Increase this time 2 or 3 seconds (accompanied with an 'ouch' for dramatic effect).

What to ask:

1. Why can you hold your hand above the second candle?
2. Where does the second candle have to be placed?
3. Why is it necessary to cover the student's view when lighting the first (front) candle?
4. Why can't the students see the second candle without looking through the glass sheet?
5. What happens if the second candle is not exactly the same distance from the glass sheet as the first?

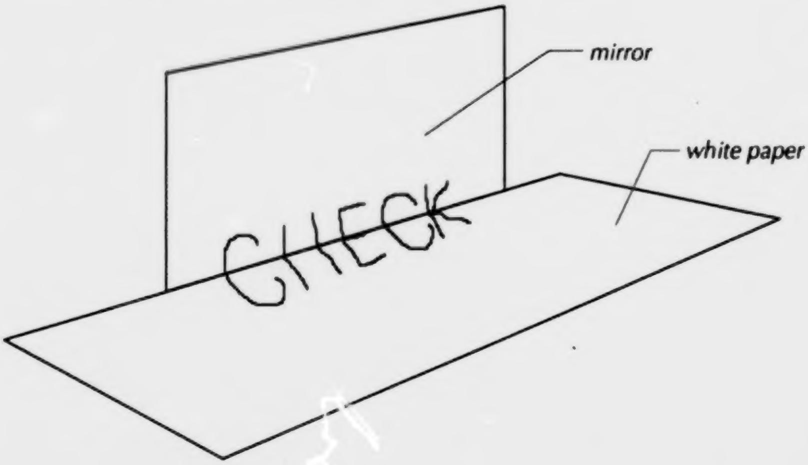
How to explain it:

It is essential that the students think that both candles are lit; this is why the front candle has to be blocked from the student's view. This is the same reason why students may not see the second candle in plain view. Once the student knows that the candle behind the glass sheet is not lit, the whole effect of the demonstration is lost.

Both candles have to be placed exactly the same distance from the glass sheet, so that the image of the front candle will coincide with the rear candle. If the rear candle is just a trifle off this exact spot, it will show a double image and again the effect of the demonstration will be lost. This shows that the **image** of an object in a mirror is located behind the mirror, exactly the same distance from the mirror as the **object** is in front of it.

2.6.03. FUNNY REFLECTIONS

What you need: 1. Unframed square or rectangular mirror.



How to do it:

1. Print the following words each on a separate piece of blank paper in large even capital letters. CHEEK, BIKE, DECIDE, BOX, CHICK, CHOKE, BOOK, HIDE, CODE, DOCK, COOKIE.
2. Cut each piece of paper in half, right through the middle of each word printed on, leaving the lower half of the word on the paper.
3. Now place the mirror vertically against the paper (perpendicular on the table) and look in the corner of the paper and the mirror.
4. Do this for each one of the words.

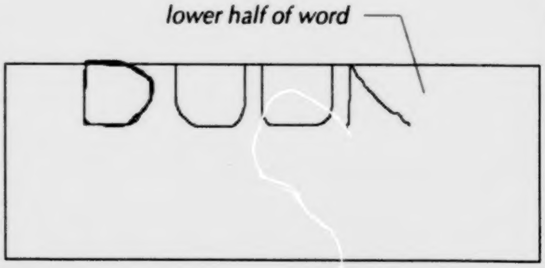
What to ask:

1. Will this work with any printed word?
2. Which of the letters, when cut in half, will appear whole with the mirror above it?
3. Which letters, when cut in half vertically, will give the other half in the mirror, when the half letter is held against it?

How to explain it:

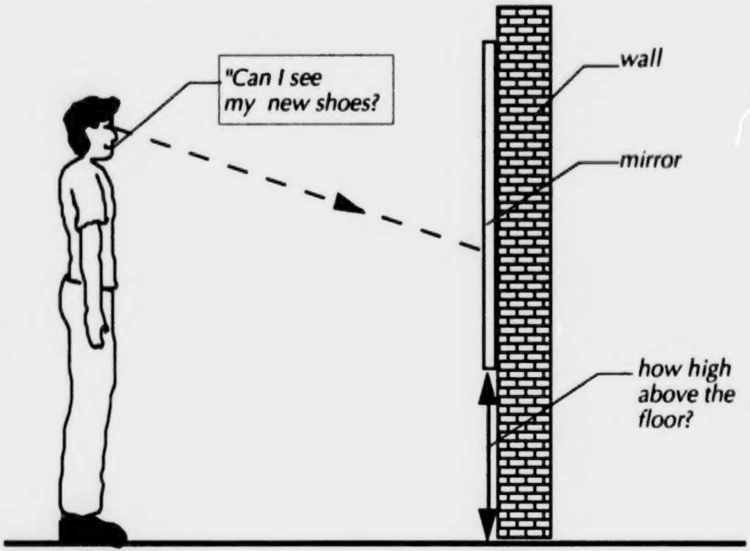
This activity will provide the student with the ability to recognize **symmetrical** objects and printed letters. It gives the student an opportunity to manipulate spatial relations. The image in the mirror shows that all images are actually formed behind the mirror.

It is only with the letters: B, C, D, E, H, I, K, O and X, that the above activity can be carried out. All other letters will not give the upper half in the mirror. The following can be cut vertically in half and the other half will show up in the mirror, when held against it: A, H, I, M, 0, T, U,V, W and X, Y. This activity gives the students an idea of **symmetry** and **symmetrical** shapes.



2.6.04. HOW HIGH TO PLACE THE MIRROR ?

What you need: 1. A meter long narrow mirror or several smaller mirrors.
2. A meter stick.


"Can I see my new shoes?
wall
mirror
how high above the floor?

How to do it:

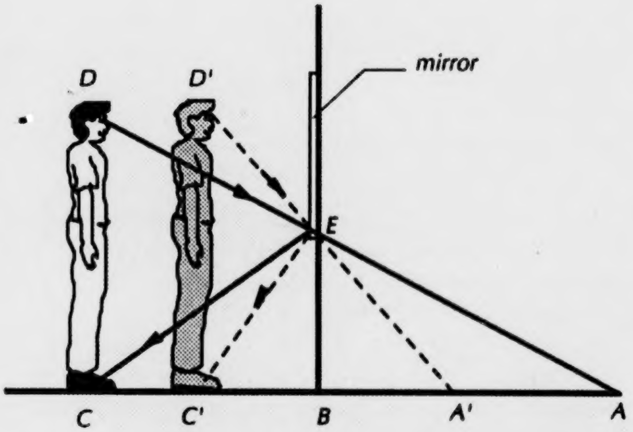
1. Pose the students with the question: "How high do I have to hang the mirror in order to see all of myself including my shoes?"
2. Record the student's predictions of the distance the mirror should be above the floor.
3. Let two students hold the mirror against the wall, a third student looks at her/himself in the mirror, and a fourth measures the maximum height of the mirror off the floor.
4. Attach the mirror at that height and let all the students see themselves in the mirror.

What to ask:

1. Does the distance, from where you stand to the mirror, affect the image of yourself in the mirror?
2. How high off the floor does the mirror have to be hung to see your feet in the mirror when standing in front of it?
3. Would a shorter person have to move the mirror in order to see his/her feet?
4. Can you draw the paths of light rays that you see coming from your shoes?

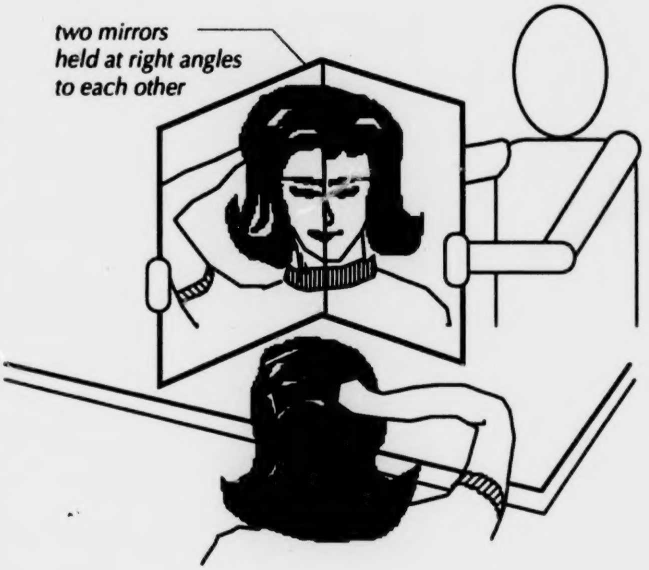
How to explain it:

Because the image of the person is exactly the same distance behind the mirror (AB=BC), the height BE is always half the height of the person (1/2CD). It does not matter where the person stands in front of the mirror. The height BE is not affected by the distance BC.



2.6.05. LOOK AT YOURSELF AS OTHERS SEE YOU

What you need: 1. Two square or rectangular mirrors without frame (one set for each group of 6 students, if dealing with a class).



How to do it:

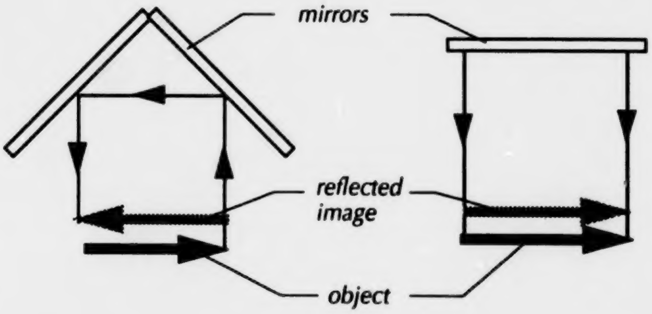
1. Have one student stand the two rectangular mirrors perpendicular to each other on the table, facing away from him.
2. Let each student observe himself in the two mirrors by looking in the corner (joint) of them, and let them touch their hair with one of their hands or wink an eye.
3. Now let the student holding the mirrors place them in one plane (in each other's extension) and let the students observe themselves again.

What to ask:

1. Why did the left hand appear on the right in the perpendicular mirrors?
2. How do light rays travel from object to mirror and back to the observer's eye?
3. What happened to your image when the mirrors were straightened?
4. How are the light rays travelling now?

How to explain it:

The light rays of the object (which is yourself) are reflected in 90° angles from one mirror to the other and then back to the eye. In a regular straight mirror, the rays bounce right back to the eye, without being reflected to another mirror. With the two mirrors perpendicular to each other, anything on the left of the object is reflected to the right hand side. All points of the object on the left side is seen an the right and vice versa (see sketch on right).

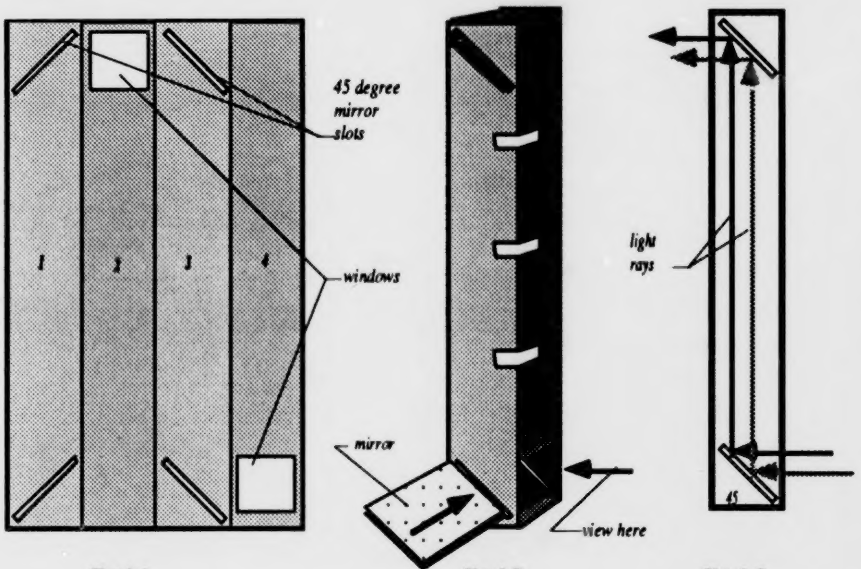


2.6.06. THE SIMPLE PERISCOPE

Materials: 1. A couple of rectangle mirrors. 2. A large piece of cardboard (1x2 ft) 3. Scissors & masking tape. 4. Protractor & ruler.

Procedure:

1. Lay the rectangle cardboard flat on another piece of cardboard and draw three lines length wise on it, so that we can divide it into four equal parts/strips. (See Sketch A).
2. Cut square windows in strip 2 and 4, and 45° angle slots in strip 1 and 2 as in Sketch A.
3. Score the cardboard on each of the three lines, so that it can fold into a square tube. Fold the cardboard along the scores and tape one edge with the masking tape.
4. Slide the mirrors into the angled slots, such that they face the open windows and tape them in place. By holding the tube horizontal you can look around corners, when holding it up right, you can look over a wall.



Sketch A Sketch B Sketch C

Questions:

1. What is the purpose of a periscope?
2. Could we achieve the same objective with one mirror instead of two?
3. Where are periscopes mostly used in our daily life?
4. What shape does the actual periscope usually have?
5. Why is the angle of 45 degrees so critical in building a periscope?
6. Would it be possible to use the periscope the other way around? - to look at things that are much lower than ourselves (lower apartments, coal mines, etc.)?
7. How would you construct a periscope that would look from balcony into another balcony at a lower or higher level? How do the mirrors and windows have to be placed?

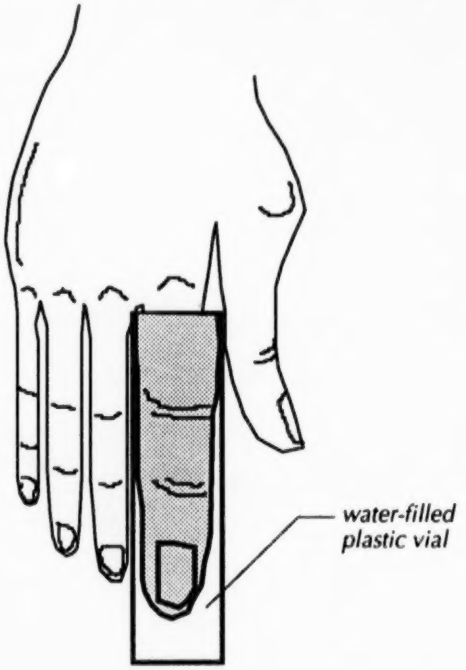
Explanation:

The purpose of a periscope is generally to look at a point that is much higher than we actually are. The most common use of the periscope is in submarines. In order to look above the water while we are in the submarine (under water), we need the periscope. Since the incoming ray makes the same and equal angle with the normal **(angle of incidence)** as the reflected ray with the normal **(angle of reflection),** it takes exactly 45 degrees to make the light to reflect at a right angle (90 degrees). This is why we need to place the two mirrors exactly at a 45 degreeangle. It is not possible to use only one mirror and achieve the same objective as the periscope, because one mirror will turn the image upside down. (see sketch)

In order to look from balcony to balcony at a higher or lower level, we need an additional mirror so that we can see things right side up. A periscope can certainly be used to look at things that are lower than us, like in mines. All we need to do is use the top mirror to look into the same periscope!

2.6.07. THE SWOLLEN FINGER

What you need: 1. A plastic vial (about 2 cm diameter) (an olive jar is quite suitable)



How to do it:

1. Fill the vial or jar about 3/4 full with water.
2. Immerse your forefinger in the water and show the difference in size with the other fingers.
3. Pour out the water and compare the size of the fingers again without the water in the vial.

What to ask:

1. Why does the forefinger look so much larger than the other fingers?
2. Did the finger look larger without the water in the vial?
3. What is the basic cause for magnification?
4. Would we get magnification by looking through a rectangular jar?
5. What other liquids can we use in the vial?

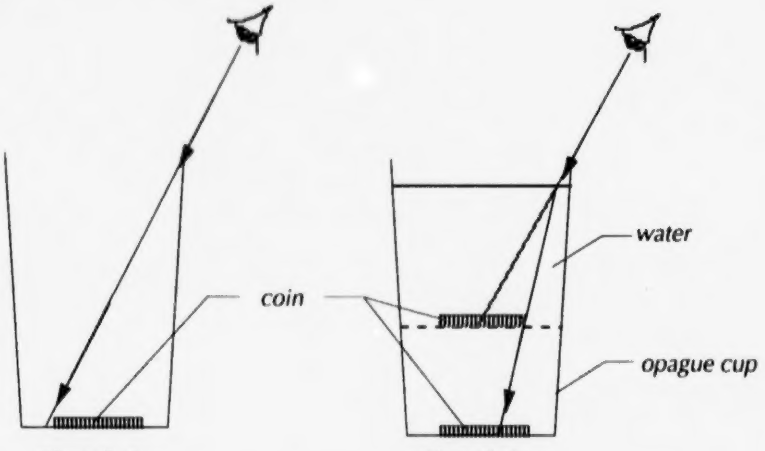
How to explain it:

The basic reason why the finger looks so much larger is that the water in the vial acts like a **magnifying lens**. The shape of the vial resembles the shape of a **convex** lens. If the container were a flat rectangular container, this lens effect would be lost. The material inside the container may be compared with the glass, which the magnifying lens is made of. Other materials that have high **refraction indices** may be used to obtain this same effect.

2.6.08. THE REAPPEARING COIN

What you need: 1. An opaque cup (foam or polystyrene).
2. A coin (or any small object that sinks in water).

How to do it:



Sketch A *Sketch B*

1. Cut the foam cup in half (make it shorter) with a pair of scissors.
2. Let the students gather around the cup, which is placed in the middle of the table.
3. Place a coin in the opaque cup (taped to the bottom with a small roll of tape with the sticky side out) and let the students look at the coin, then let them move their heads slowly back so that they just cannot see it (because it disappears behind the rim of the cup), and let them stay still.
4. Make sure that the students **do not** see the coin at this moment!
5. Now pour water into the cup until it is almost full: coin reappears!

What to ask:

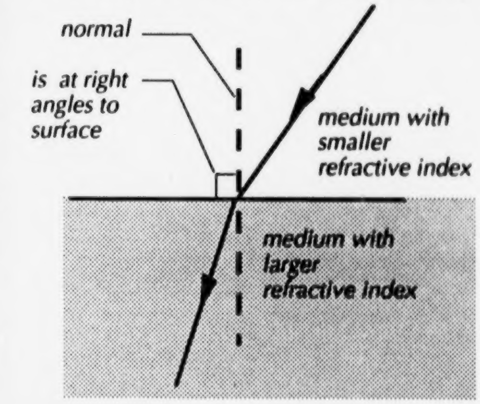
1. What made the coin disappear before the water was poured?
2. What made the coin reappear?
3. Did you have to move the position of your eyes to see the coin again?
4. What can you tell about the path of the light rays coming from the coin?
5. What other liquids can be used instead of water?

How to explain it:

The eyes were positioned, such that the light rays coming from the coin were blocked by the rim of the cup. By adding water to the cup, these same light rays from the coin now are **refracted** away from the normal, (in other words: bent down) as it travels from a medium with larger (water) to a medium with smaller refractive index (air).

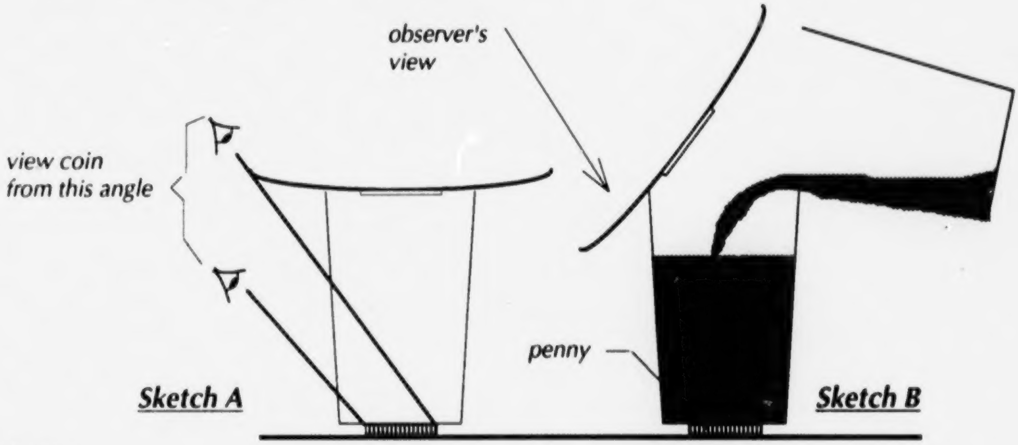
The normal is the line perpendicular to the surface separating the two media through which the light ray travels. Other liquids with high **refractive indices,** usually the denser ones, may replace water in this case, like oil, alcohol, etc.

This phenomenon is the reason why some deep waters seem to look shallow.


normal
is at right angles to surface
medium with smaller refractive index
medium with larger refractive index

2.6.09. THE INVISIBLE PENNY

What you need: 1. Two regular drinking glasses.
2. A small saucer and a penny (or other coin)

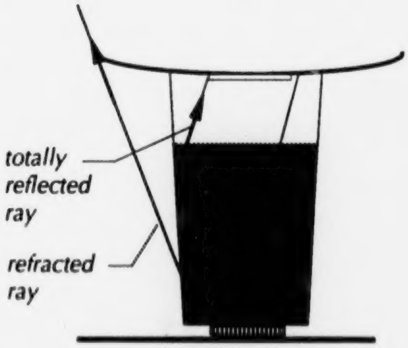


How to do it:

1. Fill one of the glasses almost full with water.
2. Cover the empty glass with the saucer and place the covered glass on the coin. Let the students observe the coin **only** from the side of the glass (Coin can be seen in Sketch A).
3. Fill this glass with water, tilting the saucer towards the observing students (see Sketch B), and place back the saucer.
4. Ask students: "Where did the penny go?" Move the glass to the side and reveal the penny.

What to ask:

1. What made the penny or coin invisible?
2. Where do the light rays of the coin travel?
3. Why do we need a saucer to cover the glass?
4. Why does the saucer have to slant towards the observer?
5. What other objects may be used in place of the coin?



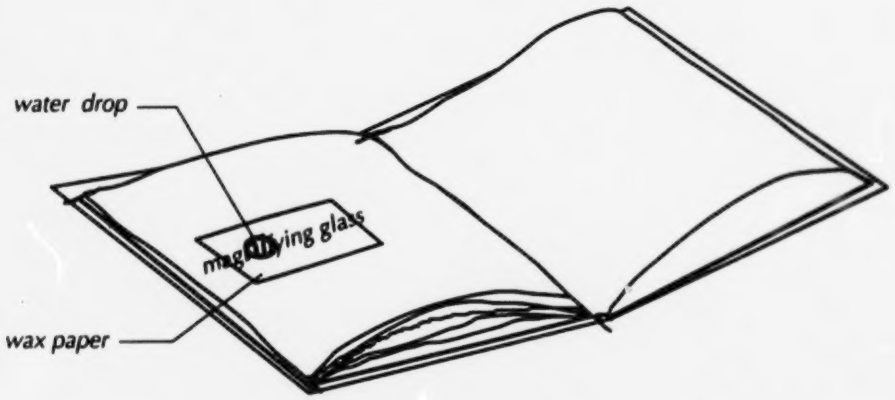
How to explain it:

The coin is still visible with the empty glass and saucer on top of it, because the light rays are not **refracted** by the air filled glass, and the coin can be seen from the side of the glass. By filling the glass with water, the material through which the rays are travelling is **denser** and thus when they hit the side of the glass they are being **totally reflected** or **refracted** very closely to the side of the glass. The saucer on top of the glass prevents seeing these rays and thus seeing the coin. The saucer has to be tilted towards the observer, while filling the glass with water, for the same reason.

Other objects in place of the coin would be, anything which is flat and thin, and that can be covered by the bottom of the glass; like a stamp, a thin button, a piece of paper, a washer, etc.

2.6.10. THE WATER DROP MAGNIFIER

What you need: 1. A roll of wax paper. 2. A small cup. 3. Small print.



How to do it:

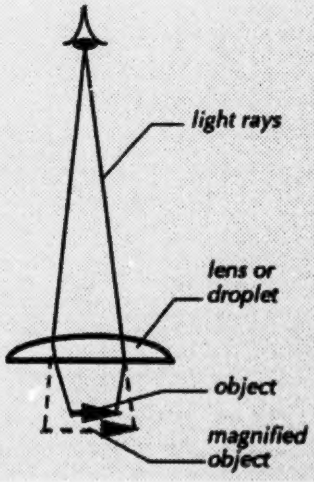
1. Tear off about a 10 cm wide strip of wax paper from the roll and distribute this to each student or to each pair of students.
2. Let the students place the wax paper over small print or anything small that they want to see magnified.
3. Come around with water in a cup and put a drop on the wax paper by dipping your finger in the water and sprinkling it on the wax paper. Make different size drops.
4. Let the students try out drops with different diameters. Which magnifies better?

What to ask:

1. How can a water drop act as a magnifier?
2. Which drop magnifies better, the smaller or the larger?
3. What property of the drop makes the amplification larger or smaller?
4. What other material could we use to replace the wax paper ?

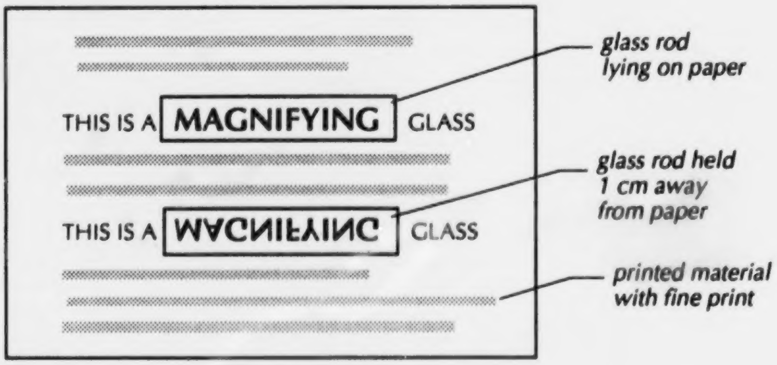
How to explain it:

The water drop on the wax paper stays rounded on the top (**convex**) because of the water-repellent properties of the paper (**hydrophobe**). This is why the water drop resembles the shape of a magnifying glass. The smaller the water drop, the stronger the **curvature**, in other words the more curved the upper surface is, and thus the stronger the magnification. Any other material that is **translucent** and hydrophobe may be used to replace the wax paper . If wax paper is not available, overhead transparencies or glass sheets may be used. Regular writing paper might be used which is made translucent. (See "The Peek-a-boo paper")



2.6.11. THE GLASS ROD MAGNIFIER

What you need: 1. Glass stirrers (one for each or a pair of students).
2. Plastic vials or olive jars.


THIS IS A MAGNIFYING GLASS
THIS IS A MAGNIFYING GLASS
glass rod lying on paper
glass rod held 1 cm away from paper
printed material with fine print

How to do it:

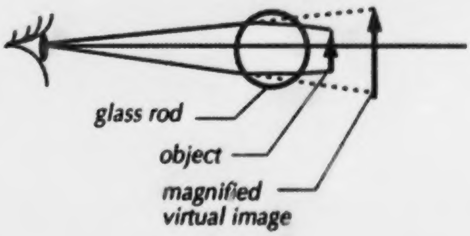
1. Distribute the glass stirrers to each or each pair of students. If glass rods are not available, fill plastic vials or empty olive jars with water (brimful), replace the top, and pass it around.
2. Let students place the glass rod or water-filled cylinder over printed material and look through the transparent cylinder.
3. Now let them hold the rod or cylinder about 1 cm away from the printed material (print is turned upside down).

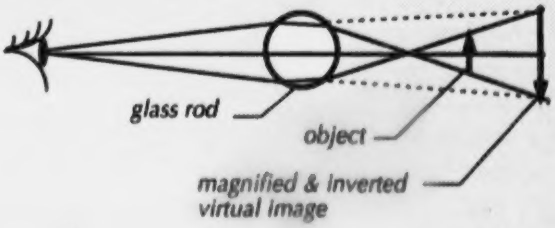
What to ask:

1. What made the rod or cylinder act like a magnifying glass?
2. How far from the printed letters could we hold the rod or cylinder before getting distortions in the letters?
3. What do we need to do in order for the letters to be seen upside down?
4. How are the light rays travelling from the object to the eye?
5. What type of image is the magnified or inverted image?
6. Would a regular magnifying glass also invert the image?

How to explain it:

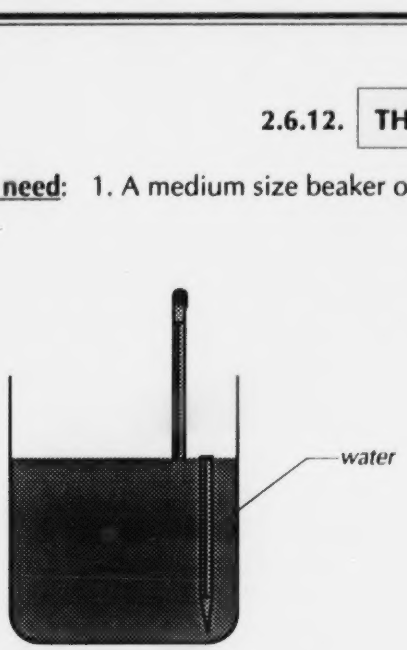
The best way to clarify the magnification and inverting of the image is by studying the light rays coming from the object and the ones that are detected by the eye. These latter are drawn in the sketches below. In both instances the image is a virtual image, one which is seen by the eye but not projected on the paper (which would be a real image).


glass rod
object
magnified virtual image

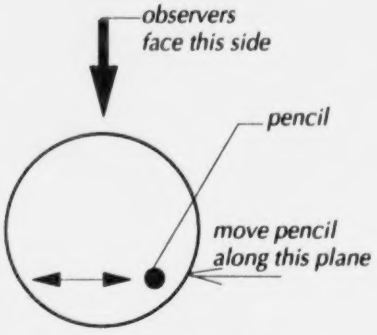

glass rod
object
magnified & inverted virtual image

2.6.12. THE BROKEN PENCIL

What you need: 1. A medium size beaker or glass jar. 2. A pencil (or pen or straw).



Sketch A


observers face this side
pencil
move pencil along this plane

Sketch B: Top view of beaker

How to do it:

1. Fill the beaker or jar about 2/3 full with water.
2. Take a pencil, pen or straw and immerse it vertically about halfway into the water, and say to the students: "I have now broken the pencil (pen or straw)."
3. Move the pencil back and forth along a vertical plane somewhat closer to the demonstrator (see Sketch B) and parallel to the observer's eyes.

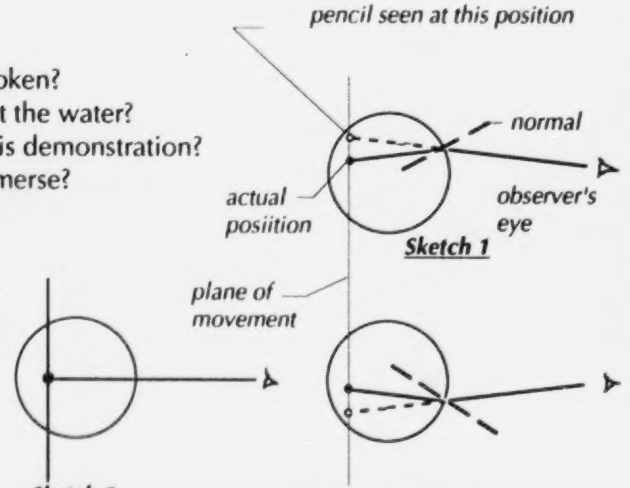
What to ask:

1. Is the pencil actually broken?
2. Why does the pencil look like it is broken?
3. Would we get the same effect without the water?
4. What other liquids can be used for this demonstration?
5. What other objects can we use to immerse?

How to explain it:

The light rays from the pencil travel from a **denser medium** (water) to a less dense medium (air). This makes the light ray refract **away from the normal** (see Sketch 1), and the pencil is seen at the extension of the refracted ray.

When the pencil is in the center of the beaker the ray is not refracted, because the light ray is travelling along the normal (Sketch 2). Sketch 3 shows the light ray from the pencil on the opposite side of the beaker.


pencil seen at this position
normal
actual posiition
observer's eye
plane of movement

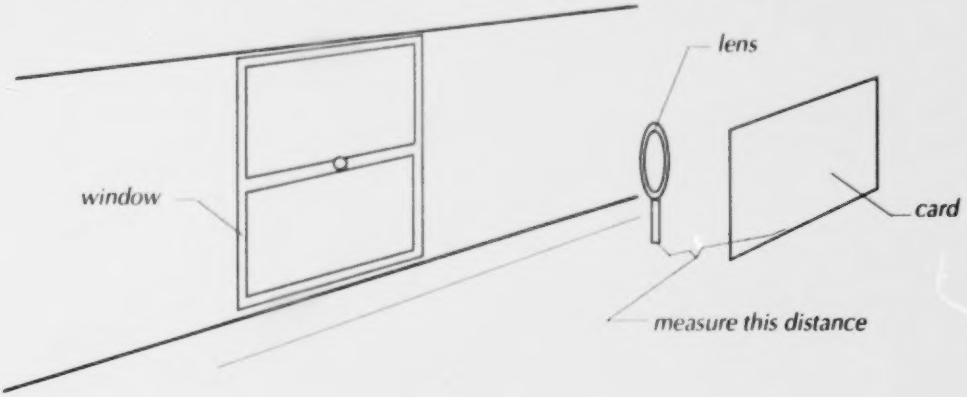
Sketch 1

Sketch 2 Pencil in center

Sketch 3 Pencil on other side

2.6.13. PRODUCE AN IMAGE OF THE WINDOW

What you need: 1. Two or three identical magnifying glasses.
2. A 3x5" paper card (7 x 12 cm). 3. A 15 cm or 30 cm ruler.



How to do it:

1. Divide the students in groups of three and distribute to each of the groups a set of the above materials (not necessary when working with one or two students).
2. Let one student hold the lens parallel to the window. (If there is no window, hold the lens horizontally parallel with the light in the room).
3. Let the second student (or other hand) hold the paper card behind the lens and move the card slowly farther away from the lens until a sharp image of the window (or light source) is formed.
4. As soon as a sharp image is formed on the card, let the third student in the group (help the student) measure the distance between the lens and the card (image distance).
5. Place two lenses together and see how the image distance changes, and three lenses and see how the image distance changes with the number of lenses (measure from the middle of the combined lenses to the card for the image distance).

What to ask:

1. What kind of lens is the magnifying glass?
2. How did the image distance change with the number of lenses?
3. What other objects can we use to produce an image of?
4. Would a near- or far-sighted person use glasses that can produce positive images like the magnifying glass?

How to explain it:

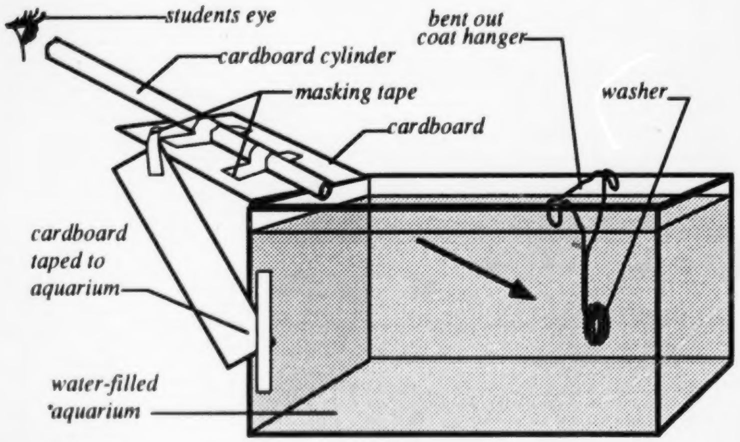
Any magnifying lens is either a **double convex** or **single convex** lens. Far-sighted people wear convex lenses, and their glasses may be used to produce the same images like magnifying glasses do. As the light rays from the window are almost parallel, the image is formed at the focal point of the lens.

Doubling the lens means cutting the image distance in half, as $1/f_1 + 1/f_2 = 1/f_t$, in which
f_1 = focal distance of lens number 1
f_2 = focal distance of lens number 2
f_t = focal distance of total systems

2.6.14. SPEAR-FISHING, ANYONE ?

Materials:
1. A small empty aquarium, or clear deep plastic tray.
2. A cardboard cylinder (core of a paper towel).
3. Two wire hangers, a piece of cardboard.
4. A washer or nut, masking tape.

Procedure:

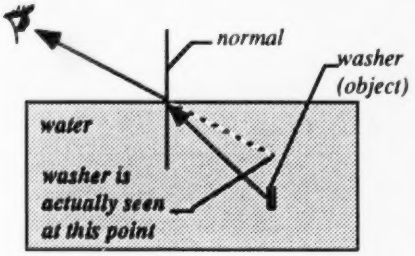


1. Fill the aquarium or clear, deep, plastic tray almost full with water.
2. Hang the washer on the coat hanger hook and bend the hanger such that it will hang over the edges of the aquarium (the washer is thus hanging in the water).
3. On the other end of the container, tape a piece of cardboard, such that it hinges around the top edge; then tape the cardboard cylinder on the cardboard.
4. Have a student look with one eye through the cylinder and direct it towards the washer. Once it is sighted, fix the angle of the cylinder by taping another piece of cardboard against the cylinder and the aquarium.
5. Now push a long straight wire (straightened from the other coat hanger) through the cardboard cylinder: Does the "spear" hit the "fish"?

Questions:
1. Where does the point of the "spear" end up in the aquarium relative to the "fish"?
2. Why will it never hit the "fish", when aimed directly at it and at an angle with the water surface?
3. When only (at what angle with the water surface) will the "spear" hit the "fish" right on?
4. Where do we have to aim the spear relative to the fish when we go spear-fishing?
5. How can we eliminate the error (and hit the fish) when going spear-fishing?

Explanation:

The light ray from the washer (or fish) under water is **refracted**, passing from water into air. Since air has a smaller refraction index compared to water, the light ray is bent away from the normal. Starting from the observing eye, the light ray is going from air into water: from **less dense to denser medium**, thus the light ray is bent towards the normal. This is the reason why swimming pools usually look much more shallow than they actually are.



In order to hit the fish with a spear, we therefore have to throw the spear lower then where we see the fish, because actually, it is swimming much lower then where we see it. Only when we are looking straight down (at 90 degrees with the water surface, along the normal) into the water, can we throw the spear right at the fish where we see it, and actually hit it too!

2.6.15. THE MAGIC OIL

Materials: 1. A clear drinking glass.
2. 2 small Pyrex test tubes.
3. Frying oil (preferably Wesson)
4. A pair of tweezers
5. A small piece of fine emery cloth

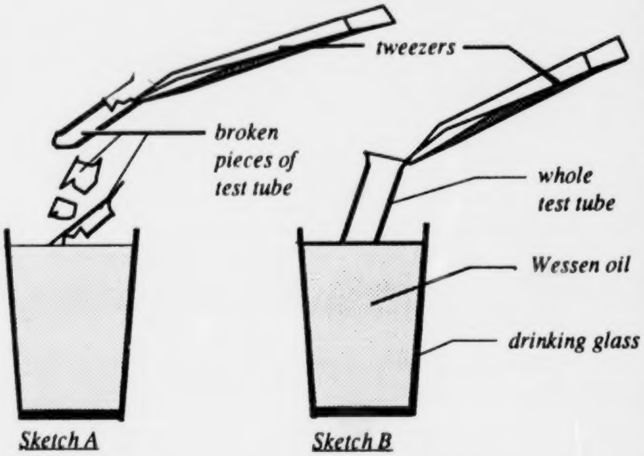
Procedure:

1. *Preparation:* a. Pour the oil into the drinking glass until it's full.

b. Take one of the test tubes, wrap it in a piece of paper, and hit it with a hammer (or other hard object) so that it will break in pieces.

c. Take the other test tube and scrape away all of the pyrex brand on the tube with the fine sand paper.

d. Place the whole test tube in the oil-filled glass, making sure that no air bubbles are left in it. Now you are ready for the demo.



2. *Demonstration*: a. Tell students that you have a glass full of magic oil, and that it can work wonders.

b. Show the broken pieces of glass tubing and plunk them in the glass of oil (leave the piece(s) with the PYREX mark out).

c. With the pair of tweezers in your hand (say abacadabra!) and slowly take the whole test tube out of the oil!

Questions:

1. Why did we have to take the PYREX mark off the test tube?
2. What did you observe when the glass pieces were put in the oil?
3. What is the reason that we could not see the PYREX glass pieces or the whole test tube, once they were put in the oil?
4. What would happen if a bubble of air was left in the test tube?
5. Would this trick also work with other brands of glass or oil?

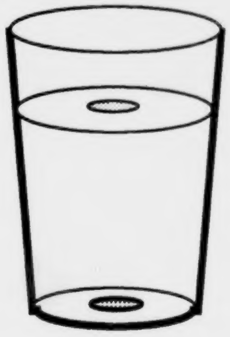
Explanation:

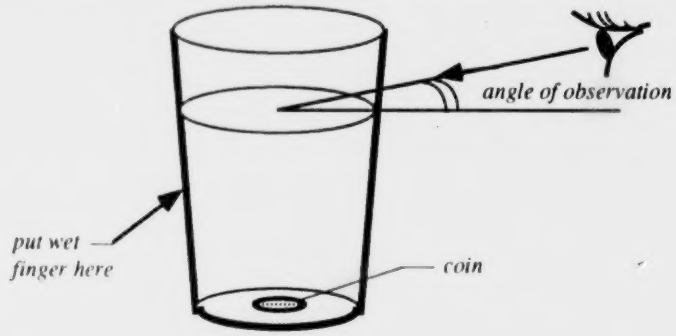
PYREX glass and Wesson oil happen to have **refractive indexes** that are very close to each other. This is the reason why the Pyrex pieces of glass were almost invisible in the oil. The light rays that pass through the oil would pass through the Pyrex glass with the **same speed**, resulting in **no refraction** when passing from oil into glass or vice versa. In other words, the light rays pass through the oil and the glass in a straight line. Store windows are made of plate glass that have refractive indexes so close to that of air, that we sometimes bump into them thinking that it was a doorway!

If an air bubble is trapped in the test tube, it will definitely be seen in the oil. Also if the PYREX label on the test tube is not removed, a floating label will be seen in the oil. It is therefore necessary to remove all labels and not leave scratches on the glass.

2.6.16. WHY DO WE SEE TWO COINS ?

Materials: 1. A penny or nickel (or any other coin).
2. A clear colorless drink glass, or beaker.





Procedure:

1. Fill the glass about three quarters full with water.
2. Drop the coin in the glass and maneuver the glass till the coin sits in the middle of the bottom.
3. Let the glass with the water and coin now stand still on a table and observe the surface of the water from about a 15-20 degree angle.
4. Touch the far side of the glass with a dry finger: does anything happen to the image of the coin?
5. Wet your finger, then touch the far side of the glass with the wet finger: what happens to the image of the coin?

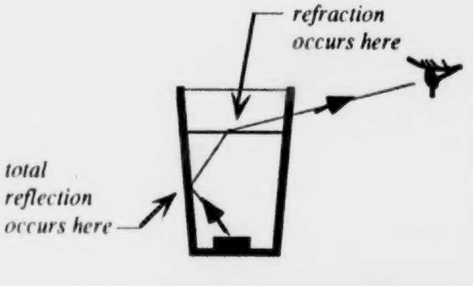
Questions:

1. What makes us see another coin on the surface of the water?
2. Does the image of the coin get inverted?
3. What do we see when the angle of observation is larger?
4. Why is the image of the coin disappearing when the glass wall is touched with a wet finger?
5. Where is reflection occurring, and where refraction?

Explanation:

There is **total reflection** of the image of the coin occurring at the back wall of the glass, then **refraction** occurs at the surface of the water.

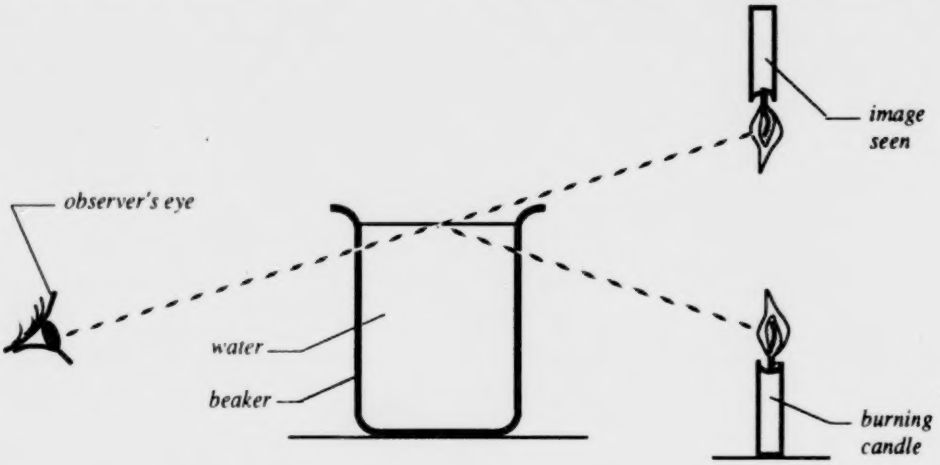
If a wet finger is placed on the back wall where the total reflection is supposed to occur, a layer of water is actually placed on the outside of the glass. This equalizes the refraction indexes on both sides of the glass (because they are of the same medium: water), and total reflection is thus eliminated.



If a dry finger is held at the same spot, it will not be seen, because on the outside of the glass is air rather then water. When we look from a denser medium (water) to a less dense medium (air) at a particular angle, total reflection occurs, and thus the finger is not seen.

2.6.17. USE WATER AS A MIRROR ?

Materials: 1. A small candle & matches. 2. A 400 ml beaker or regular large drinking glass.



Procedure:

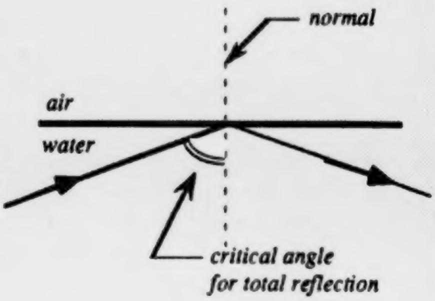
1. Light the candle and place it on a shelf or stand at about eye level in a dark corner of the room (when sitting it should be somewhat lower but still at eye level).
2. Fill the beaker or glass full with water.
3. Hold the beaker a little higher than the candle, and look up against the water surface, such that the candle flame will reflect in lt - the height of the beaker may need adjusting in order to see the reflection of the candle flame (see Sketch above).

Questions:

1. Why do we see an inverted candle flame image?
2. How can water give a reflection like a mirror?
3. Why do we need a dark background to see the reflection?
4. What other substances will act similarly like the water?
5. What property was different between the water and the air?
6. Would different gases or gases of different densities be able to act like a mirror?

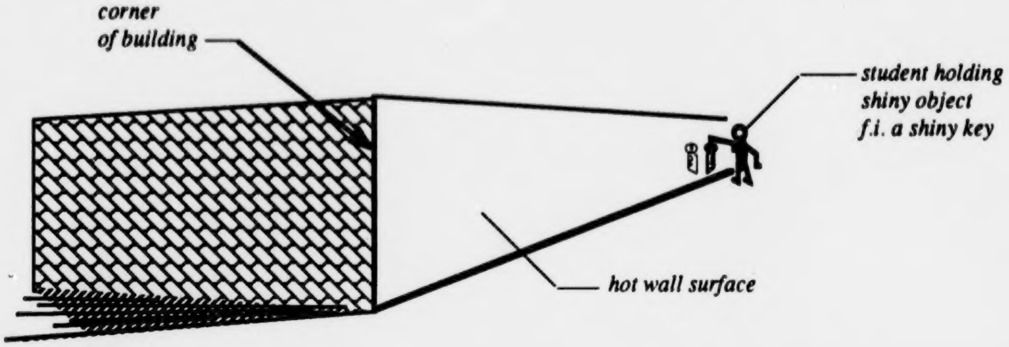
Explanation:

The boundary between water and air act like a mirror because water has a higher density than air and its **refraction index** is also higher. When the **angle of incidence** is too large (exceeding the **critical angle), total reflection** occurs rather than refraction of the light rays (see Sketch on right). Hot air bordering on cold air will act similarly. Hot air over a road on a hot summer day will give one the illusion of water on the road. Mirages over a desert are formed in the same way.



2.6.18. THE REFLECTING BRICK WALL

Materials: 1. A long (minimum 10 m) wall on a hot sunny day.
2. A bright metallic object (like a shiny key).



Procedure:

1. Take the class outdoors on a bright sunny day. Stand at one end in front of a brick or concrete wall against which the sun is shining.
2. Let one of the students hold a shiny metallic object, like a key or knife, about 5 to 10 cm from the wall, such that you can see it.
3. Observe an Image of the object in the wall! (If you don't see the image, move in closer to the wall or let the student move the object closer to the wall).

Questions:

1. What made the wall act like a mirror?
2. Why does it have to be a sunny day, where the sun shines against the wall?
3. What other surfaces would act in the same manner?
4. In what other situations may we encounter the same phenomena?
5. Why would a shiny object work better than a dull object?
6. Why can we only see a reflection when we are so close to the wall?

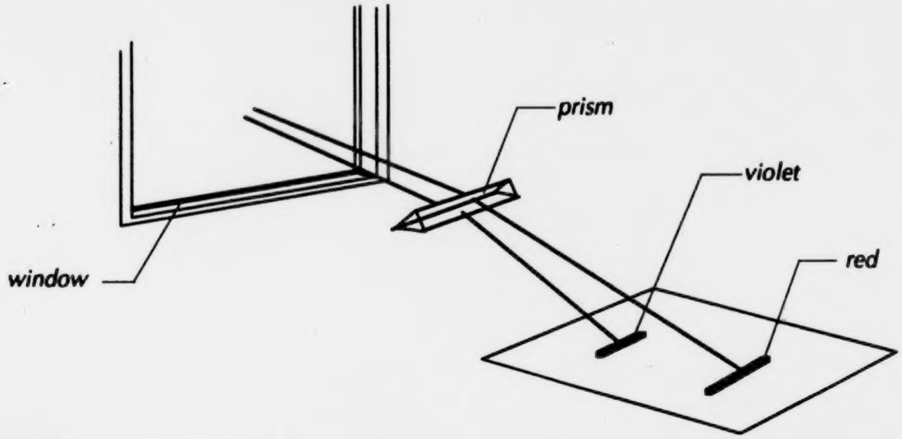
Explanation:

When the sun shines against the wall, it heats the wall up and the hot wall heats the air surrounding it. This hot layer of air has a different **index of refraction** as compared to cooler air. It therefore acts as a different medium against which light can be **totally reflected**. This angle of total reflection occurs only at very large angles of incidence. This is why we have to be so close to the wall to see the reflection of the shiny object. A shiny object works better because it can easily be seen from such a distance.

This same phenomena occurs in the **mirages** that we see over deserts. The reflecting medium in this case is colder air, which hovers above the hot air over the desert sands. Another example is when we are driving on a hot day, we may see far off on the road a shiny spot as if it was wet or oily, but on approaching it, it suddenly disappears. Here the hot air above the road acted like a mirror, giving total reflection only at large angles of incidence.

2.6.19. MAKE RAINBOW COLORS

What you need: 1. A triangular prism (glass). 2. A blank piece of paper and sun rays.



How to do it:

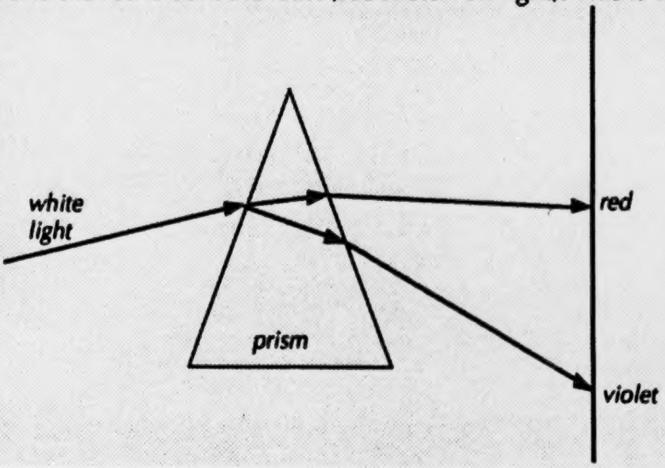
1. Place a blank sheet of paper on the table top where the sun rays shine through the window.
2. Hold a triangular glass prism in the sun rays and turn it around its lengthwise axis until a rainbow spectrum falls on the blank paper. (Crystal from a chandelier can be used)

What to ask:

1. How can white light give the colors of the rainbow?
2. What are the colors of the rainbow?
3. Which color is bent most? (Farthest away from the straight line?)
4. What source can we use instead of sun rays?

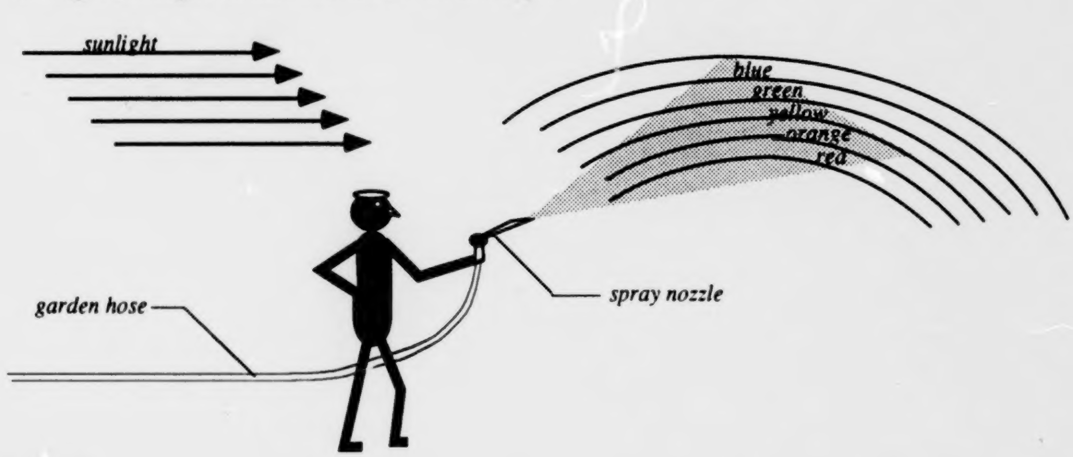
How to explain it:

White light is made up of the rainbow colors: violet, blue, green, red, yellow and orange. The violet ray is **refracted or bent** most, and the red is bent the least (see sketch on right). This is why the sky stays blue when the sun sets in the west and the sun becomes red. The moisture in the atmosphere would act as prisms and scatter or **separate** the blue light out. Viewing the sun rays from a 90° angle, the color will appear blue (sky) whereas looking directly into the setting sun, the color is red.



2.6.20. MAKE YOUR OWN RAINBOW

Materials: 1. A garden hose + sprayer nozzle (connected to water outlet).
2. Bright sunlight (when sun is low in the sky).

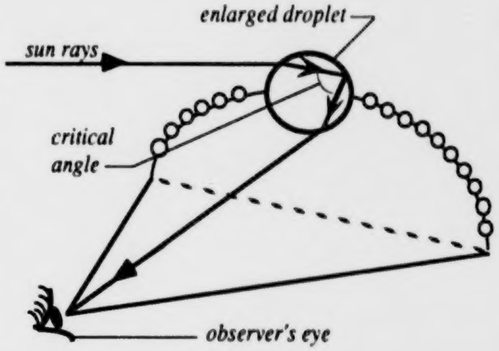


Procedure:

1. Take the class outdoors on a bright sunny day. Attach your garden hose to the outdoor tap, hold the spray nozzle in your hand and position yourself such that you face away from the sun (the sun behind you).
2. Squeeze the spray nozzle and produce a fine spray of water in front of you, and Voila! A beautiful rainbow!

Questions:

1. What are the conditions for seeing a rainbow?
2. When is a rainbow actually seen in nature?
3. What makes the different colors in the rainbow?
4. What color is on top, what color on the lower side?
5. Why is the rainbow always circular/ a segment of a circle?
6. Why is the rainbow never a square, triangle, or straight line?
7. Why does the sun always have to be behind us to see a rainbow?
8. Where do we see rainbows, besides In the sky?



Explanation:

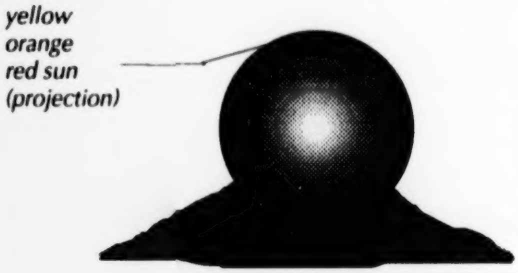
The conditions for seeing a rainbow are: the sun has to be behind us, we have to look away from the sun, and facing the fine droplets in the sky (clouds after a rain). These droplets can be a few meters, a few hundred meters or a few thousand meters or kilometers away from us.

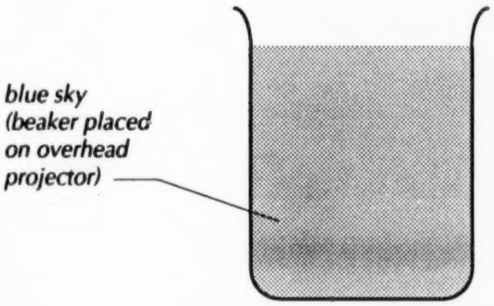
The rainbow is always a segment of a circle, because it is a part of the circular base of a cone. These are the only droplets that we can see because of the **critical angle** that gives a **total reflection** of the sun ray falling into it. The blue color is always on top since it is the most refracted one (with the largest refraction). Other places where we could see rainbows are: fountains, waterfalls in bright sunlight (provided we stand in the right position).

2.6.21. THE SIMULATED SUNSET

What you need: 1. A beaker or glass jar.

2. Sodium thiosulfate ($Na_2S_2O_3$) and concentrated sulfuric acid (H_2SO_4).





How to do it:

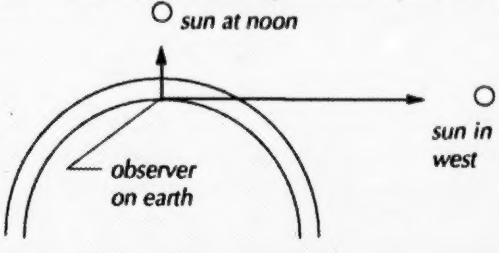
1. Cut a circular hole in a large piece of paper with the same diameter as the beaker or jar; place it on the overhead projector and a water-filled beaker over the hole.
2. Dissolve a scoop of sodium thiosulfate in the water until no crystals can be distinguished in the water.
3. Pour a few ml of concentrated sulfuric acid in the solution, stir, stand back and observe.
4. When the color of the beaker (seen from the side) starts to turn bluish, draw students' attention to the color of the sun (projection) and the color of the sky (side view of beaker). (When the sun's color gets orange-red, a torn piece of paper may be pushed under the beaker to simulate a mountain.)

What to ask:

1. How do you think the bluish color in the beaker was created?
2. Why was the sideview of the beaker blue and the projection of it yellow or orange?
3. How is this demonstration similar to the actual sunset?
4. Why does the sun get red when it sets in the west?

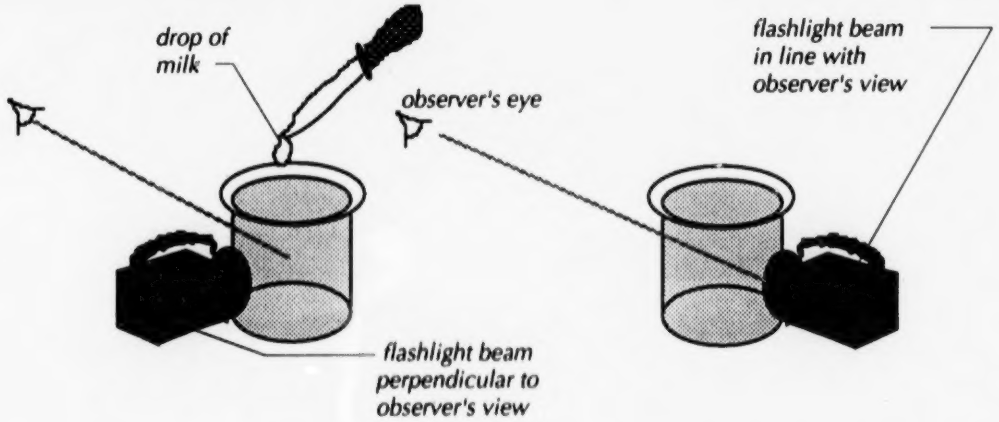
How to explain it:

White light is **dispersed** or **scattered** into the colors of the rainbow if it hits a prism. When the sun sets in the west we are looking through a much thicker layer of atmosphere compared to noon time. This means that when we look to the west, we are looking through more dust and moisture particles. Each of these particles acts like prisms, scattering white light into red at one end of the spectrum and blue at the other end. Blue has the shortest wavelength and refracts with the largest angle. The reaction of H_2SO_4 + $Na_2S_2O_3$ precipitated sulfur (S) slowly out of the solution, simulating the increasing concentration of the dust and water particles.



2.6.22. THE CONFUSED FLASHLIGHT

What you need: 1.A strong flashlight. 2.A large beaker & medicine dropper & stirrer. 3.A few ml of regular cow milk.


drop of milk
observer's eye
flashlight beam in line with observer's view
flashlight beam perpendicular to observer's view

How to do it:

1. Fill the beaker nearly full with water.
2. With the medicine dropper, place one drop at a time of milk in the water and stir.
3. After each drop of milk added to the water, shine the flashlight through the water by holding it on the side of the beaker: let the light beams shine perpendicular to and into the student's view.

4 Keep adding the drops of milk to the water until the light shone into the student's view beoomes red.

What to ask:

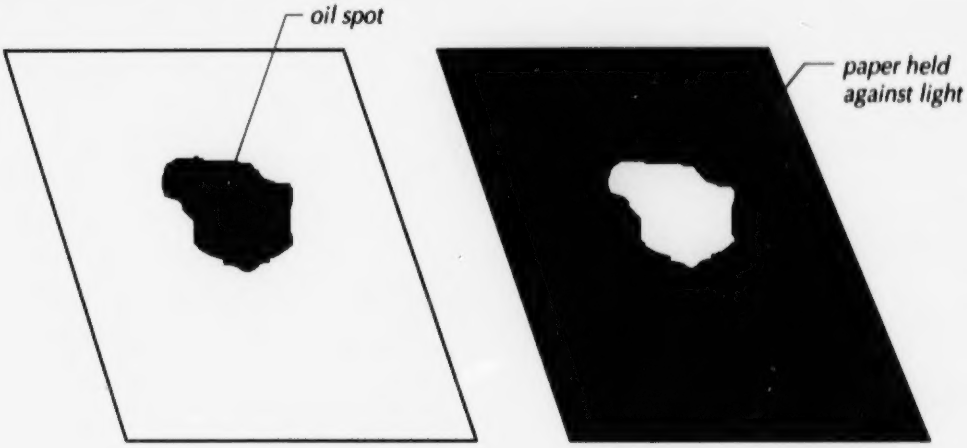
1. What made the color of the light change?
2. What purpose does the milk have?
3. If the water were the earth's atmosphere and the flashlight were the sun what can the milk droplets be equated with?
4. Which of the colors do you think are refracted most? Which the least?

How to explain it:

Increasing the milk droplets in the water is like increasing the water and dust particles in the atmosphere. When the sun moves to the west approaching sunset, the atmosphere through which we are looking is much thicker. This means that we are actually looking through more dust and water particles. When we look to the west during sunset, we look directly into the sun rays, seeing the sun as a red ball. Looking up towards the sky when the sun is in the west, still leaves the sky blue. Th e sun rays are now perpendicular to the direction of our view. This difference in color is caused by the **refraction** of the blue light. The shorter the **wavelength** (blue), the more it is bent or refracted by milk droplets. The light with the longer wavelengt(red) is not as much refracted and this is why the light from the flashlight is red when we look directly into it (through the beaker with milk). (See "Make Rainbow Colors")

6.2.23. THE PEEK-A-BOO PAPER

What you need: 1. Any kind of writing or typing paper.
2. Regular frying oil (motor or machine oil will do). 3. Paper towel.



How to do it:

1. Distribute sheets of paper to each one of the students.
2. Dip a corner of paper towel in the oil and come around to each of the students.
3. Make an oil spot in the center of each of their papers .
4. Give the students some paper towel, and let them wipe the excess oil off the oil spot.
5. Let the students look through the spot by placing the paper over printed or written material.
6. Let the students hold the paper against the light and compare the lightness and the darkness of the spot with the rest of the paper.

What to ask:

1. How can oil make opaque paper translucent?
2. What does it mean in terms of light rays when something is opaque or translucent?
3. Why is the oil spot dark compared to the rest of the paper when the light falls on the paper ?

How to explain it:

The oil **penetrates** all the pores and fibers of the paper when it touches it. This makes the paper completely **impregnated** with oil and thus more uniform for the light to pass. Thus the light rays go through the oil spot and get **reflected** by the rest of the paper. This is why the oil spot looks darker, because the light rays are not reflected back. When the light source is behind the paper the opposite happens: light passes through the spot and it hits the observer's eye, whereas the rest of the paper blocks the light and appears darker.

A DEMONSTRATION IS

A HUNDRED-THOUSAND WORDS

CHAPTER 7

WHAT ARE THE PROPERTIES OF SOUND ?

OBJECTIVES:

After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:

a. Recognize the correct explanation of an observed event based on each of the sub-concepts,
b. Explain in their own words which of the sub-concepts is determining the course of an event,
c. Distinguish true from false statements concerning each one of the sub-concepts;
d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

all in relation to the following sub-concepts:

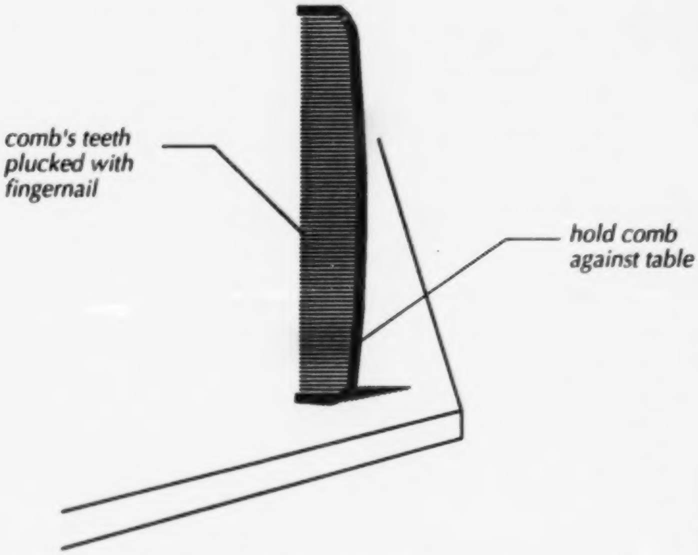
- — Sound is produced by vibrating objects.
- — The loudness of sound is determined by the distance form the source, the intensity of the vibration, and the surface area of the vibrating object.
- — The pitch of note is determined by the mass of the vibrating object: the larger the mass, the lower the pitch.
- — In resonance, the resonating object has the same frequency of vibration as that of the sound source.
- — Sound does not travel through a vacuum.
- — Sound travels faster through liquids and even faster through solids compared to gases.
- — The speed of sound through air is around 340 m/s.

2.7.01. WHICH AMPLIFIER WORKS BEST ?

What you need: 1. A cheap polystyrene comb (the stiff kind) for each student.

How to do it:

1. Hold a comb in the air and pluck the teeth with your fingernail.
2. Ask students: "How can I amplify the sound?"
3. Hold the end of the comb against the table top and pluck again.
4. Distribute different combs to each of the students and let them try to hold it against different material in the class/room and listen which of them gives the best amplification.
5. Point out to the students that the different lengths of the teeth give different pitches (simple tunes might be plucked by the teacher).



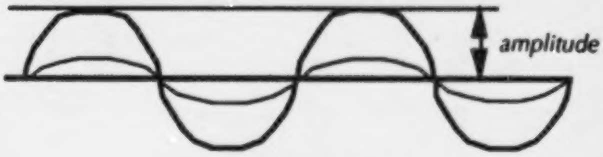
What to ask:

1. How did the sound get amplified?
2. Why do we hear the sound louder when the comb is held against other materials?
3. Which factors are influencing the loudness of a sound?
4. What material is the best amplifier for the comb?
5. What made the different pitches in the plucking of the comb's teeth?

How to explain it:

In holding the comb against the table top while plucking the comb's teeth, it was not only the teeth and the comb that were vibrating but the whole table top vibrated with it. This means an increased surface of the vibrating object, which is the main reason for an increasing loudness or an amplification.

The factors that are affecting the loudness of a sound are: 1. distance from sound source; 2. the amplitude of the wave, i.e., how hard the teeth are plucked; 3. the surface area of the vibrating object.

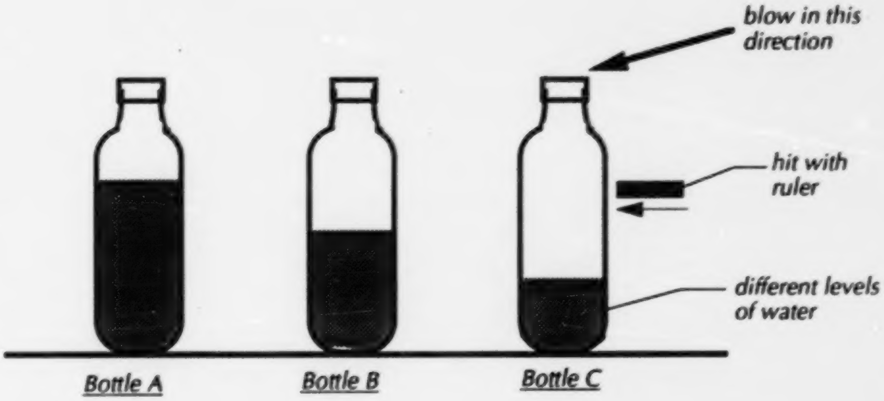


SOUND WAVE

In general wood sheets and wooden boxes are the best materials for quality in sound amplification. This is why sound boards (for the piano), guitar and violin bodies, and speaker boxes are all made out of wood.

2.7.02. THE REVERSING PITCH

What you need: 1. Three identical empty bottles. 2. A wooden stick or ruler.



How to do it:

1. Fill the three identical bottles with different amounts of water, and ask the students: " Which will give the highest tone when I hit it on the side with the ruler?"
2. Lift the bottle with 2 fingers at the neck and hit the side of each bottle with the ruler and listen to the pitch of the tone.
3. Now ask the students: "Will bottle C always give the highest pitch?"
4. Blow over the bottle mouth, by placing your lower lip on the bottle rim and blowing a narrow stream of air almost horizontally over the mouth. Listen to the tone/pitch.

What to ask:

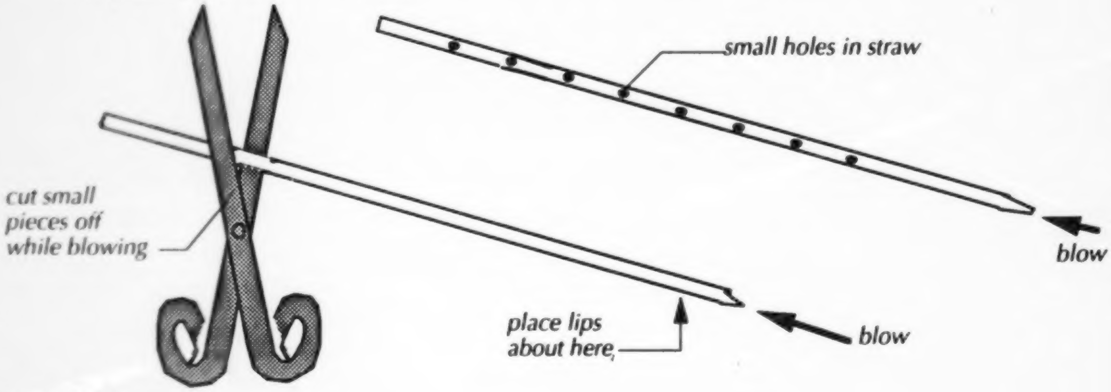
1. What was vibrating when the bottles were hit on the sides?
2. What produced the tone when the bottles were blown into?
3. What is generally affecting the pitch of a tone?
4. Would different liquids of the same height in the bottles affect the pitch of the tone? When hitting the bottle? When blowing over the bottle opening?

How to explain it:

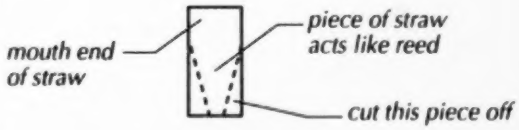
When the bottles were hit on the side with the wooden ruler, the bottle and the water vibrated to produce the sound pitch. The more water there was in the bottle, the lower the pitch. When blowing over the bottle mouth, the air above the water in the bottle vibrated to produce the tone. The larger the column of air in the bottle, the lower the pitch. If we generalize over these two events we can say that **the more the mass of the material vibrates, the lower the pitch it produces.** This is why the lower and deeper tones on the guitar or piano are coming from the larger and longer strings. By shortening the strings (by placing the finger on a fret), the higher the pitch obtained. By using different liquids in the bottles, but filling them to the same height, the pitch would probably be different when hit on the side (because of the different masses of the liquids), but stay the same when blown over the mouth (because the air column stays the same).

2.7.03. THE STRAW OBOE

What you need: 1. Two plastic drinking straws and one with a larger or smaller diameter.
2. A pair of scissors.



How to do it:



1. Cut small holes on one side of a straw, about 1 to 1.5 or apart from each other.
2. Flatten one end of both straws and cut triangle pieces out.
3. Place this end of the straw with holes in the mouth, holding your lips just where the cut ends, and blow until an oboe sound is produced. (Shifting the straw somewhat in or out of the mouth might help obtaining the sound.)
4. Place three fingers of the left hand on the farthest three holes and three fingers of the right hand on the nearest three holes of the straw; and open or close holes for the different pitches.
5. Now blow the straw with no holes. Make the oboe sound, take the pair of scissors and cut small pieces off the straw while blowing.
6. Slide a straw that is slightly larger or smaller over or into the straw oboe, and while blowing slide the smaller or larger straw in or out - the straw trombone!

What to ask:

1. What was actually producing the sound?
2. What pitch did we get when all holes were closed, compared to when all holes were open?
3. What does opening or closing a hole in the straw really mean in terms of vibrating an air column?
4. Which musical instruments are based on this principle?

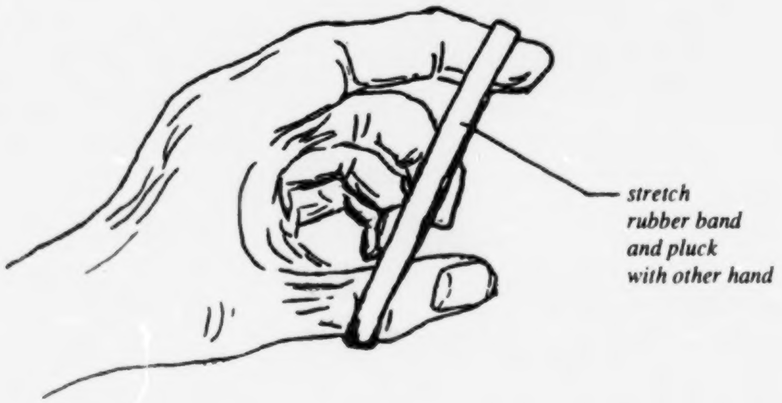
How to explain it:

This demonstration especially shows that the **pitch** of a note is determined by the length of vibrating air. By cutting the end of the straw we are actually making two reed-like protrusions, which when air blown through them, will vibrate and produce the oboe sound. The **air column** in the straw is **vibrating** with it and produces the pitch. With the holes in the straw we are able to make the vibrating air column longer or shorter, by either closing or opening a hole or several holes at a time.

This principle is applied in the flute, clarinet, oboe, saxophone, and their varieties in soprano, alto, tenor and bass constructions.

2.7.04. PLUCK A RUBBER BAND

What you need: 1. A small medium thick rubber band.



How to do it:

1. Place the rubber band between thumb and forefinger, and stretch it a little.
2. Hold it close to your ear and pluck it with the other hand.
3. Stretch the rubber band by widening the gap between thumb and forefinger and pluck again. What pitch do you hear now?

What to ask:

1. Did the pitch of the sound change after widening the gap?
2. Which properties of the rubber band changed while being stretched?
3. What property changes when a guitar string is tightened?
4. Which properties do not change when a guitar string is tightened?
5. How do these properties compare to those of the rubber band?
6. In what ways can we change the pitch of a guitar string?
7. How could we change the pitch of the rubber band?

How to explain it:

When the rubber band stretched and was plucked again, the pitch of the sound was staying about the same, if not getting a little lower. This is definitely contrary to what one would expect, which is a higher pitch for the stretched rubber band.

When a guitar string is tightened, the pitch becomes higher, because the tension is higher, thus the **string vibrates with a higher frequency;** the length and the density of this string, however, is staying constant.

With the stretching of the rubber band, all three properties: tension, length, and density change. The higher tension tend to increase the pitch, but this is compensated by the increase of the length, which tends to lower the pitch.

When the length of the rubber band is held constant, the pitch changes similarly like a regular guitar string. This can be done by stretching the rubber band over an empty open box.

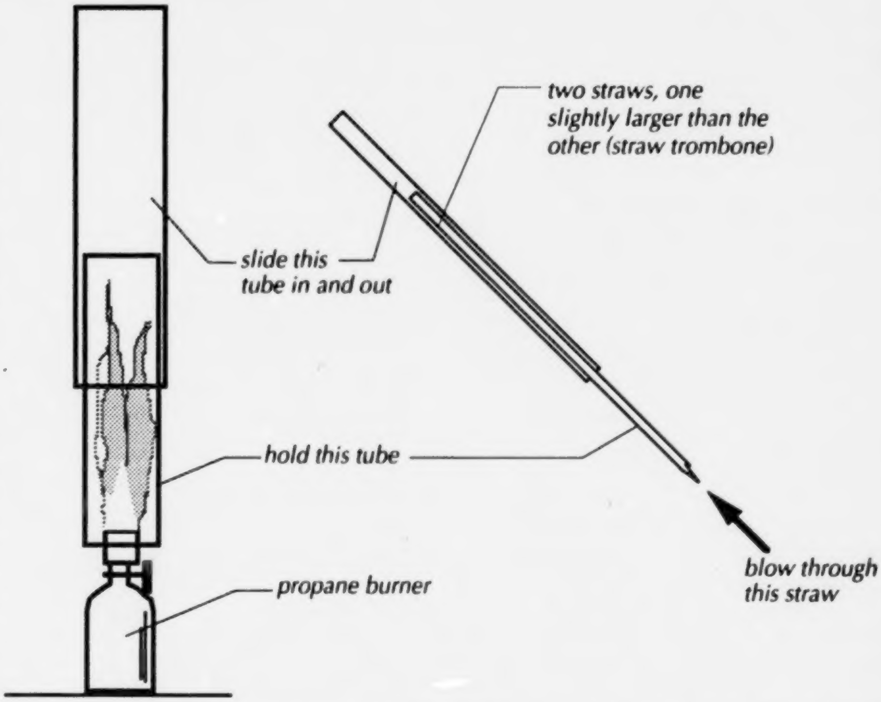
2.7.05. THE PIPE AND STRAW TROMBONES

What you need: 1. Two rigid plastic tubes (one slightly larger in diameter than the other so that they can slide into each other, about 40-50 cm length each).

2. Two straws (plastic drinking), with the same specifications as above.
3. A propane torch or Bunsen burner.

How to do it:

1. Light the propane torch or Bunsen burner and turn it to the largest setting with the air valve open.
2. Hold one of the rigid tubes vertically and lower it slowly over the flame until a resonating tone is produced.
3. Slide the larger tube up and down over the first one while holding them both over the flame (trombone effect).
4. Flatten one end of the straw and cut small triangle pieces out of each side to make a straw oboe (see Event 2.7.03).
5. While blowing through this oboe, producing the tone, slide the other straw over the first one in and out (trombone effect).


two straws, one slightly larger than the other (straw trombone)
slide this tube in and out
hold this tube
propane burner
blow through this straw

What to ask:

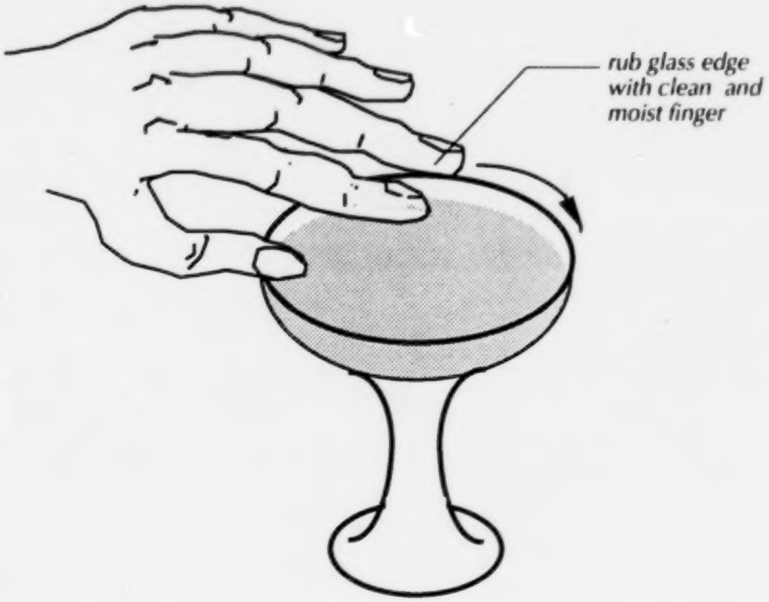
1. How was the resonating tone in the rigid tube produced?
2. What changed the pitch in the sliding tubes?
3. What produced the tone in the straw oboe?

How to explain it:

The heat of the flame in the tube suddenly expands the air in it and the air begins to **oscillate** up the tube, resulting in a **resonating** tone: a **standing wave** is created in a tube with open ends. The longer the tube, the longer wavelengths are produced in the standing wave and thus the lower the tone. The same goes for the sliding straws, except that the sound is produced in the standing wave and thus the lower the tone. The same goes for the sliding straws, except that the sound is produced by the **vibrating reeds.** These are made to vibrate by blowing the air stream between them.

2.7.06. THE SINGING GLASS

What you need: 1. A wine glass (or any other thin drinking glass with a smooth rim).
2. A little vinegar or dilute acid.


rub glass edge with clean and moist finger

How to do it:

1. Wash your hands with soap and place the wine glass on the table.
2. Dip the fore- or middle-finger in a little vinegar, hold the wine glass steady with the other hand (hold base down on table) and rub the rim of the glass with the dipped finger.
3. The rubbing should be done rather slowly (if the finger slips without giving off a sound, then either the glass rim is greasy or your finger is not quite clean).
4. Pour a little water in the wine glass and rub again. Notice the pitch change.

What to ask:

1. What is the purpose of the vinegar?
2. Why do the hands and glass have to be clean?
3. What is the finger actually doing when it rubs the glass rim?
4. What is the pitch doing when water is added to the glass?

How to explain it:

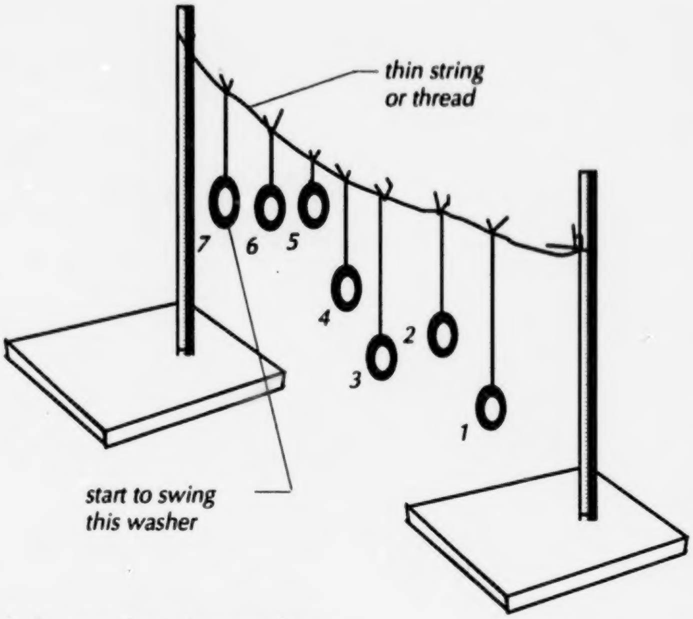
When the finger is rubbing against the rim of the glass, it is not supposed to just slide over it, but it catches and slides in very quick succession. It is just like hitting the side of the glass with a hard object, softly and in very quick succession. It almost works like a bell hammer. As soon as the first few vibrations are produced, they make the glass **resonate,** because the pitch produced is exactly the same as that of the glass itself. By adding water to the glass, the vibrating mass is increased and thus the pitch got lowered.

2.7.07. THE TUNED-IN WASHERS

What you need: 1. Two upright stands and 7 identical washers.
2. Light string or sewing thread.

How to do it:

1. Place the two upright stands about 50 cm apart and attach a string between them at the same height.
2. Now tie the short lengths of string to the seven washers.
3. Hang the washers on the horizontal string at the following lengths:
   washer No. 1 - 20 cm. No. 5 - 5 cm.
   washer No. 2 - 15 cm. No. 6 - 10 cm.
   washer No. 3 - 20 cm. No. 7 - 15 cm.
   washer No. 4 - 15 cm. (somewhat farther apart).
4. Start to swing washer No. 7 and observe the other washers.



What to ask:

1. Why did washer No. 2 and No. 4 swing with No. 7?
2. If washer No. 2 were swinging first, which one would swing with it?
3. If washer No. 1 were swinging first, which one would swing with it?
4. How can we compare this event with a sound source and resonating objects?

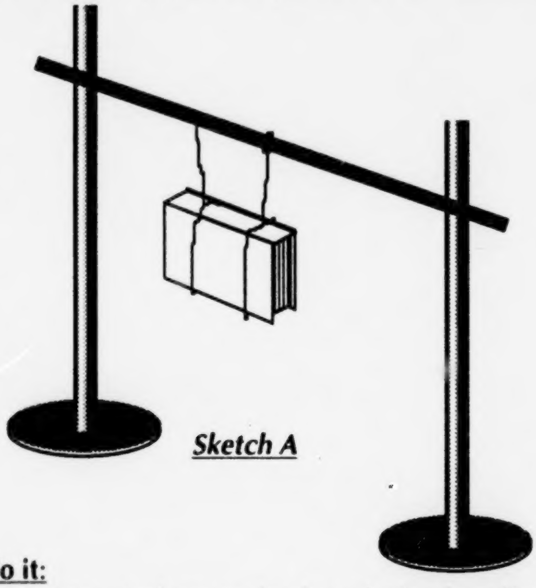
How to explain it:

This demonstration is another excellent illustration of the phenomenon of **resonance.** When washer No. 7 starts to swing, washers Nos. 2 and 4 will swing with it. Washer No. 7 can be compared with the source of vibration and washers Nos. 2 and 4 are **"tuned in"** with or have the same **frequency of vibration** as washer No. 7. The same happens when washer 2 or 4 is started with the swinging first. The washers that have the same string length will swing with the original "swinger." So when washer No. 1 is started to swing, then only washer No. 3 will swing with it.

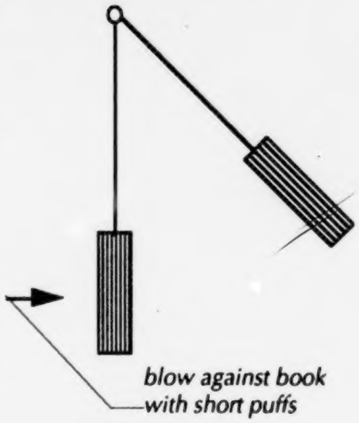
In resonance, the resonating object has to have the same frequency of vibration as the source. Sometimes the source of vibration can be the object itself and then it will increase its own vibrations. This was the case with the collapsing Tacoma bridge in Washington state, which started to vibrate because of a high wind that blew against the bridge.

2.7.08. THE SWINGING BOOK

What you need: 1. A paperback pocketbook. 2. A horizontal bar stand and string.



Sketch A



Sketch B

How to do it:

1. Tie two strings to the paperback pocketbook and hang it from a horizontal bar stand (see Sketch A). Or if stand is not available, let someone hold up the strings.
2. Hold the book about 45° from the vertical line out and ask the students: "Would I be able to blow against the book until it is this far out?" (Anticipated answer: "No way").
3. Let the book hang back vertically and blow with puffs in phase with the swings of the book. (Just like pushing someone on a swing in the park.)

What to ask:

1. Why is it not possible to blow the book to 45 from the vertical line with one huff?
2. What is most important to get the book swinging higher and higher with the puffs?
3. How can we stop the book from swinging without touching it?
4. How can we compare the swinging of the book and the blowing, with sound and resonance?

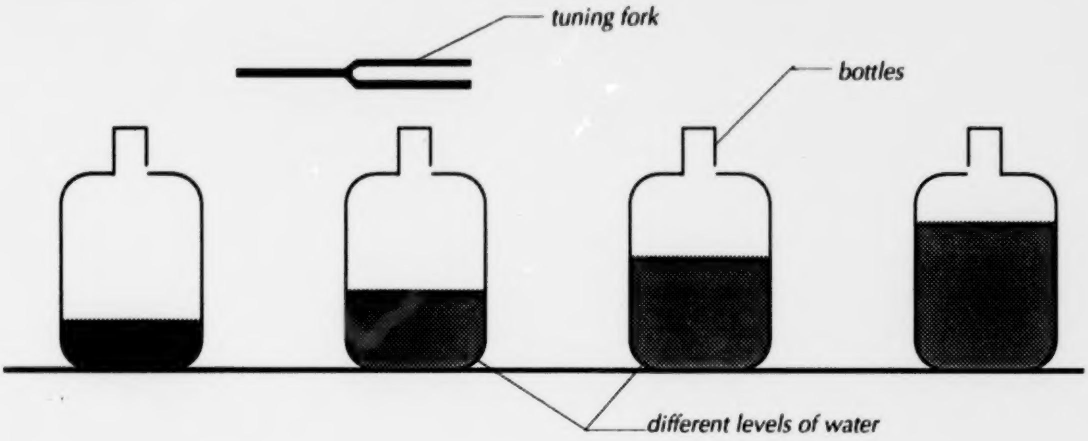
How to explain it:

This is an excellent demonstration to illustrate what **resonance** actually is. When we deal with resonance there is always a source or **origin of vibration** (sound) and an object which is **resonating** with the source of vibration.

The huffing against the book can be compared with the source of vibration and the swinging of the book as the object which resonates with the source. When the huffing is in phase with the swinging book, it will swing higher and higher. In sound terms: when the sound source has the same **frequency** as the vibrating object, it will **resonate** with the sound source. In order to stop the swinging of the book, the huffing has to be done out of phase or in opposite phase with the swinging. Again, in terms of sound we would say: to stop the object from resonating, the source has to have a different frequency than the vibrating object, or the object should vibrate with a different frequency than the source of vibration.

2.7.09. THE SINGING BOTTLE

What you need: 1. Three or four identical bottles. 2. A tuning fork.



How to do it:

1. Place the four bottles on the table and fill them with different amounts of water.
2. Strike the tuning fork and listen to the tone.
3. Fill one of the bottles with just enough water, so that the air column above the water (when blown into) will vibrate with the same tone as the tuning fork.
4. Place this bottle back in row with the other bottles, strike the tuning fork and hold it over each of the four bottles (stopping a second above each one, then moving on to the next).

What to ask:

1. Which bottle is "singing" with the tuning fork?
2. Why are the other bottles not "singing" with the tuning fork?
3. How can we make the other bottles "sing" too?
4. What is it that makes the bottle resonate with the tuning fork?
5. Where do we find this event applied in daily life?

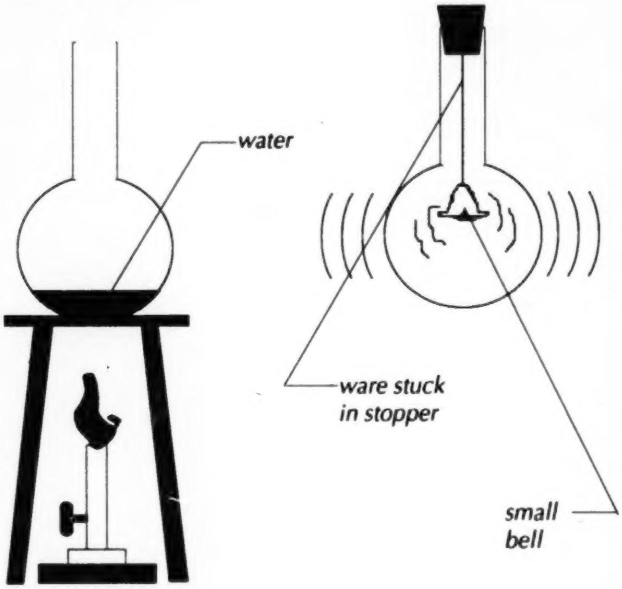
How to explain it:

Since only one bottle's water height was adjusted such that the air above it would vibrate with the tone of the tuning fork, this bottle is the only one that is **resonating** with the tuning fork. The air columns of the other bottles were either too long or too short to "sing" or **resonate** with the tuning fork. The **frequency** of the tone in these latter bottles is not the same as that of the tuning fork, and thus they do not vibrate with it. For a further explanation of resonance see Events 2.7.06 and 2.7.07.

An application of this event in daily life is encountered when a certain tone is sounded in front of a guitar or open grand piano; only certain strings that have the same pitch or octaves thereof, will resonate with the original tone or pitch.

2.7.10. THE SOUNDLESS BELL

What you need: 1. A round-bottomed flask (or flat-bottomed).
2. A small bell (that fits through the neck of the flask).
3. A rubber stopper and short piece of iron wire.
4. A Bunsen or propane burner & stand, a cloth.



How to do it:

1. Attach the small bell to the wire and stick the other end in the rubber stopper. Adjust the length of the wire so that the bell will hang in the center of the flask when closed off.
2. Close the flask off with the stopper and bell, shake the flask and let the students listen to the tinkle of the bell (a faint high note should still be detected).
3. Take the stopper off, pour about 20 ml of water in the flask, and heat it over the Bunsen or propane burner and stand, until boiling.
4. Let the water boil for a minute or so and then shut the flame off, and immediately insert the stopper with the attached bell (hold the flask with the cloth to prevent burning of fingers).
5. Let the flask cool off for a minute, shake the flask again and try to detect the same faint high note of the bell.

What to ask:

1. Why did the ring of the bell disappear after boiling water in the flask?
2. What is the purpose of boiling water in the flask?
3. If sound does not travel through a vacuum, could we hear rocket exhaust in outer space?
4. Why can sound not travel through a vacuum?

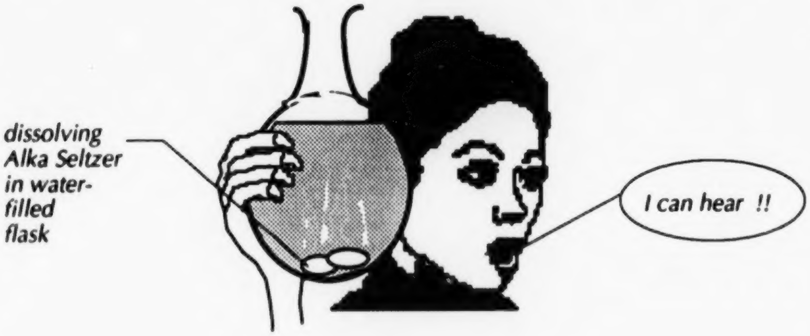
How to explain it:

In order for human beings to hear a sound, sound waves or vibrations have to reach their ear drums, whether it is through a gas, a liquid or a solid. There has to be a **medium** in order for waves to travel from one place to the other. We hear sound and noises around us, because air is present everywhere. In the flask we created a partial vacuum. By boiling water, steam was produced and this pushed most of the air out of the flask. After the flask cooled, the steam condensed back into water and almost no air is left in the flask. This is why the bell could not be heard after the water had been boiled in the flask.

Any sound sources that are located in outer space (i.e., in a vacuum), are **not propagating any sound.** This is one of the reasons why we do not hear the tremendous sun explosions and the space travel sounds from the surface of the earth.

2.7.11. LISTEN TO THE POPPING BUBBLES

What you need: 1. A can of fresh soda pop. 2. A round-bottomed flask or drinking glass. 3. A tablet of Alka Seltzer (or other tablet which gives off gas bubbles when dissolved in water).


dissolving Alka Seltzer in water-filled flask
I can hear !!

How to do it:

1. Open a can of soda pop and place it immediately against your ear (or pour the soda in the glass, and place the glass against your ear). If soda pop is not available, do point 2.
2. Fill the flask or drinking glass with water and plunge a tablet of Alka Seltzer in it. Place the flask or glass immediately against your ear.
3. Listen to the popping bubbles.

What to ask:

1. What kind of sounds did you hear in the can or glass?
2. Why couldn't you hear the popping bubbles through the air?
3. What do you do when you want to hear something better?
4. What medium did the sound travel through?
5. Would you think that sound travels easier through liquid or gas?

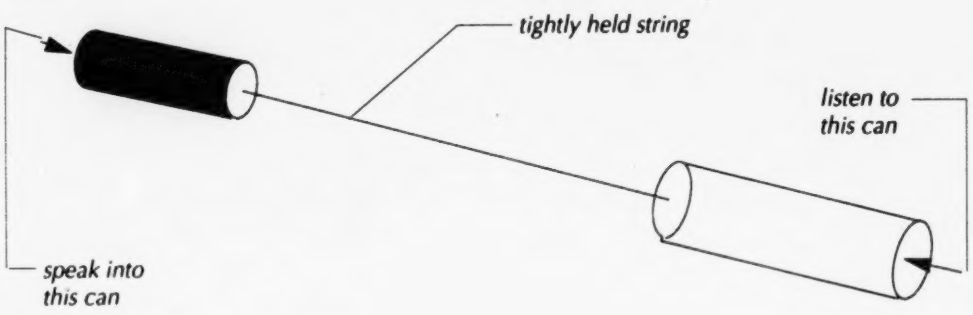
How to explain it:

The source of sound in this case is formed by the bursting bubbles of carbon dioxide from the soda pop or the Alka Seltzer tablet. The bursting bubbles create waves in the liquid, which reach the can or glass container. This vibrates in turn and the air close to the ear carries the vibrations to the ear drum.

As soon as we bring the source of sound closer to the ear, we can hear it better. Just like in the ticking of a watch or someone's heartbeat, that we like to hear, we must bring the ear closer to the source. **Sound travels through liquids faster and easier compared to doing that in gases.** This is why the tapping of two rocks can be heard better under water than above water (try this in a swimming pool).

2.7.12. THE POP CAN TELEPHONE

What you need: 1. Two empty soda pop cans. 2. A string (same as length of the room).
3. Nail & hammer, a can opener.



How to do it:

1. Cut one end of the two soda cans completely open with the can opener.
2. Punch a hole in the center of the other end with the nail and hammer.
3. Thread the string through the holes, such that the closed ends face each other and tie a large knot at the end of the string, so that it will not slip out of the hole.
4. Let a student stand at the far end of the room, hold the cans keeping the string tight, and alternately speak softly and listen in the can (see sketch).

What to ask:

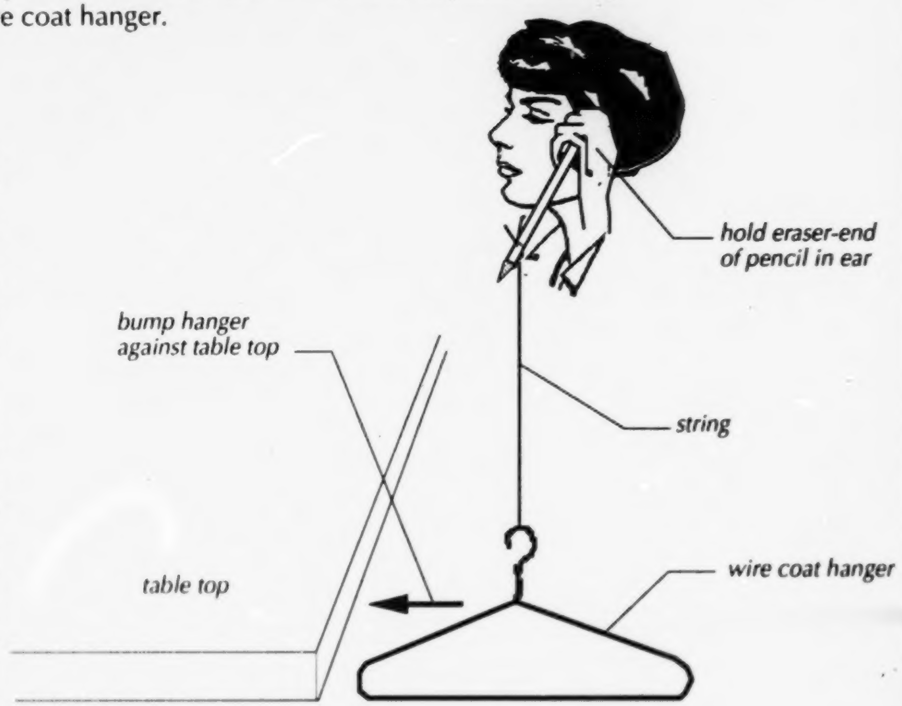
1. How did the sound travel to the student's ear?
2. What did speaking in the can do to the bottom of the can?
3. Why did the string have to be held tightly?
4. Would this set-up work if we had a solid pipe or bar instead of the string between the two cans?
5. Could a whisper be heard from one end of the room to the other end, through the 'telephone'? Through the air?

How to explain it:

By talking into the can, the **vibrations** from the vocal chords make the air in the can vibrate. These vibrations are transferred to the bottom of the can, which in turn vibrate. The same vibrations are traveling along the string in **longitudinal waves,** making the bottom of the other can vibrate. The air in the receiving can is thus reproducing the exact vibrations of the first can, resulting in the same voice of the original sender. A whisper could not be heard through the air compared to a whisper through the 'telephone'. The waves travel through the solid string in the latter case, and it is much more facilitated. **Sound travels faster and easier through solids than through gases.**

2.7.13. THE COAT HANGER CHURCH BELL

What you need: 1. A pencil with eraser end. 2. A short piece of string.
3. A metal wire coat hanger.


hold eraser-end of pencil in ear
bump hanger against table top
string
table top
wire coat hanger

How to do it:

1. Tie the string tightly to the pencil (opposite eraser end) and to the hook of the coat hanger.
2. Place the eraser end of the pencil in the ear and while holding it there, swing the coat hanger and let it hit a solid object (or hit the hanging coat hanger with another pencil).
3. If a pencil with eraser end cannot be found, wind the string around your index finger, put the finger in your ear and let the hanger hit the edge of the table!

What to ask:

1. What do you hear with the ear in which the pencil or finger is placed?
2. Why didn't you hear the coat hanger vibrations through the air?
3. What was the source of the sound?
4. Describe how the vibrations reached the ear from the source.
5. What other objects could we hang from the string for a source of sound?
6. What would you do to hear someone's heartbeat?
7. What other applications of this principle do you encounter in daily life?

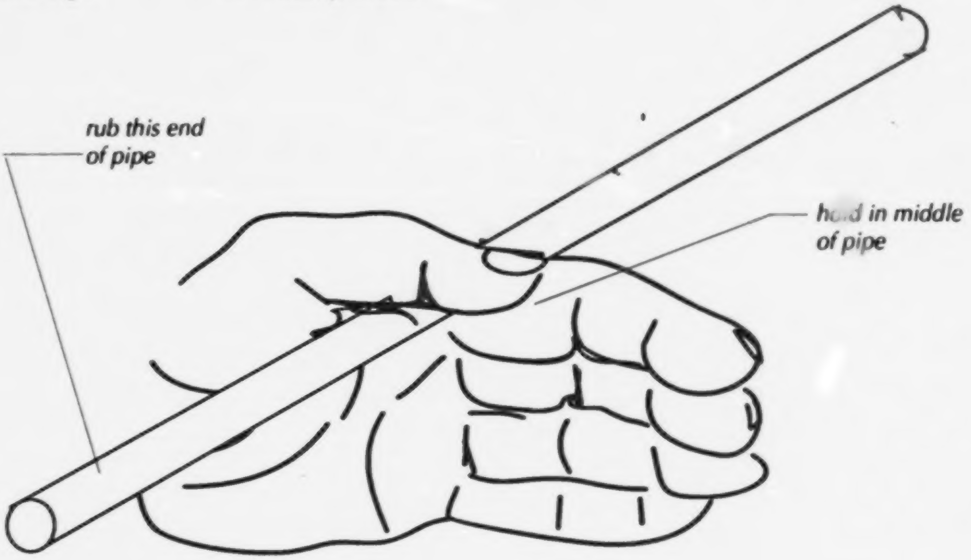
How to explain it:

The coat hanger hitting a solid object would **vibrate** and act as the **source of the sound.** The vibrations travel through the string and the pencil (or finger) to the ear drum. As the string and pencil (or finger) are solids, it is much easier for the sound waves to travel through them than through the air. It is the vibrations of the pencil (or finger) that are immediately transferred to the ear drum, that make the sound so audible.

Similarly, we place our ear against someone's chest, in order to hear his/her heartbeat. By placing our ear against the railroad tracks, we can hear a train approaching long before we can hear the train sounds through the air.

2.7.14. THE RESONATING BAR

What you need: 1. An aluminum solid bar or hollow pipe (3/4" or 2 cm diameter and about 3' or 1 m long). 2. A damp cloth.


rub this end of pipe
hold in middle of pipe

How to do it:

1. Let the aluminum bar balance on your right hand, by holding it between forefinger and thumb in the middle of the bar.
2. Rub the left hand side of the bar with the damp cloth, slowly and gripping the bar rather lightly (try this several times until a high pitched tone is produced).
3. If the rubbing does not succeed, tap the bar vertically on a hard surface or hit the end of the bar with a hard object.
4. Stop the vibration by holding the bar on either end of the center with the left hand.

What to ask:

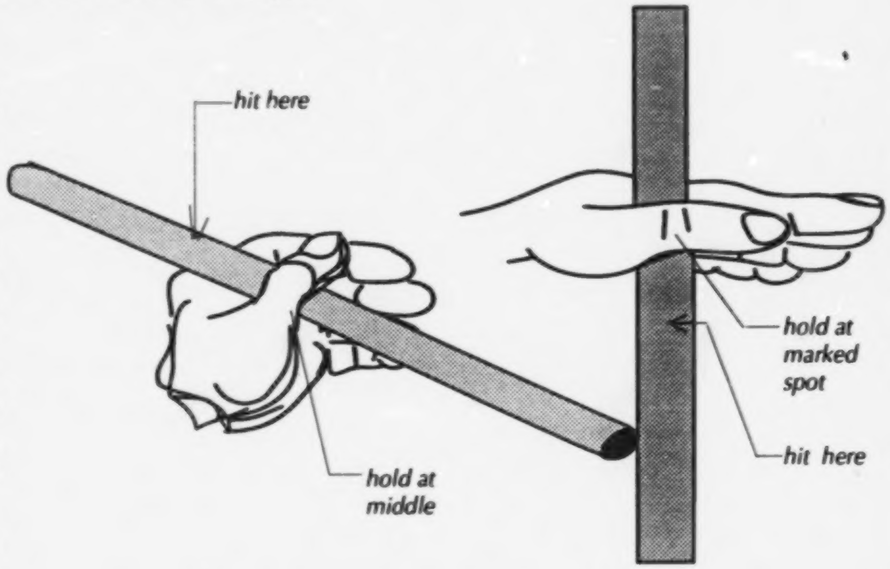
1. What did the rubbing of the bar do to it?
2. Why does the rubbing as well as the tapping produce the same tone in the bar?
3. Would hitting the bar on the side produce the same tone?
4. Why can the vibration be stopped on the side of the bar that was not rubbed or hit?

How to explain it:

The rubbing with the damp cloth of the aluminum bar made the cloth slip and grab, slip and grab alternately, causing a **longitudinal** or **lengthwise wave** in the bar. The tapping at the end of the bar causes the same longitudinal wave, which will travel throughout the whole bar, not only on the side where the vibration originated. This is why the vibration can be stopped by holding even the end of the bar that was not rubbed. When the bar is hit on the side instead of at the end, a **transverse wave** is created, which has a much longer wavelength and thus a much lower tone or pitch compared to the longitudinal wave.

2.7.15. THE MULTIPLE TUNING PIPE

What you need: 1. An aluminum pipe (1" or 2.5 cm diameter and about 3' or 1 m long).
2. A golf ball or other hard rubber object.



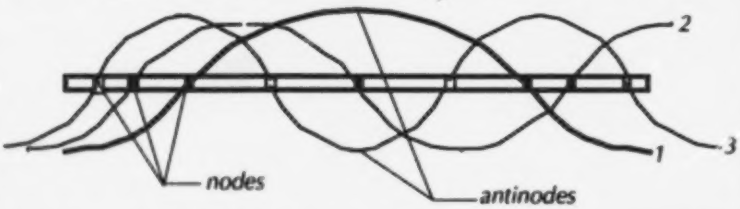
How to do it:

1. Let the pipe balance by holding it with the right hand between thumb and forefinger in the middle of the pipe.
2. Hit the pipe with the golf ball close to the middle of the pipe.
3. With a grease pencil or other marker, place marks on the pipe at places: 13, 25, 35, and 39 cm on each side away from the center (these are approximate distances: the correct spots may be found by holding the pipe at a spot and hitting it with the golf ball; the correct spot will be revealed by a pure resonating tone).
4. Hold the pipe between thumb and forefinger vertically at the marks and hit the pipe with the golf ball. What tones do you hear?

What to ask:

1. Why did the pipe give different tones?
2. Did holding the pipe at different spots determine the tone?
3. Could the vibration continue by holding the pipe at more than one spot? More than two spots? Which of the spots?
4. Holding which of the spots would give the same tone?
5. Holding which of the spots on the pipe would give the highest pitch? The lowest pitch?

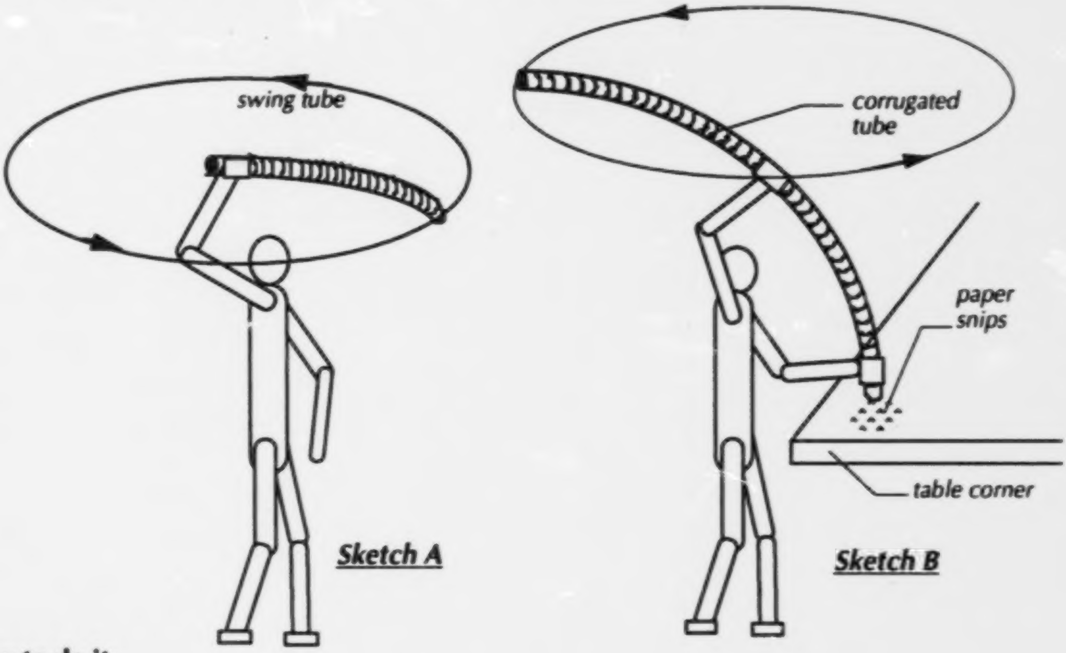
How to explain it:



By holding the pipe at one spot and hitting it with the golf ball, we are getting a **vibration** in the pipe, resulting in a **standing wave,** detectable by a certain tone/pitch depending on where it is held. The spot 25 cm away from the center gives the lowest pitch, whereas the spots 13 and 39 cm from the center give the highest pitch. This is because of the shorter wavelength produced.

2.7.16. THE TWIRLING BUGLE

What you need: 1. A corrugated plastic tube (a swimming pool drain hose or vacuum hose, corrugated on the inside; about 6' or 1.5 m long, 4 cm diameter).



How to do it:

1. Hold the plastic tube in one hand at one end, and swing it in a vertical plane or above your head, first slowly, then faster and faster (different pitches will be heard—see Sketch A).
2. Tear a piece of paper up into a few small snips and leave them in a heap on the edge of the table. Hold with one hand the stationary end of the tube above the snips and with the other hand, swing the tube (the pieces of paper will be flying all over - see Sketch B).

What to ask:

1. What made or produced the sound?
2. Why did we get different pitches by twirling the tube faster?
3. Why did the note skip in pitch; what is the next higher pitch called?
4. Which way is the air flowing in the tube?

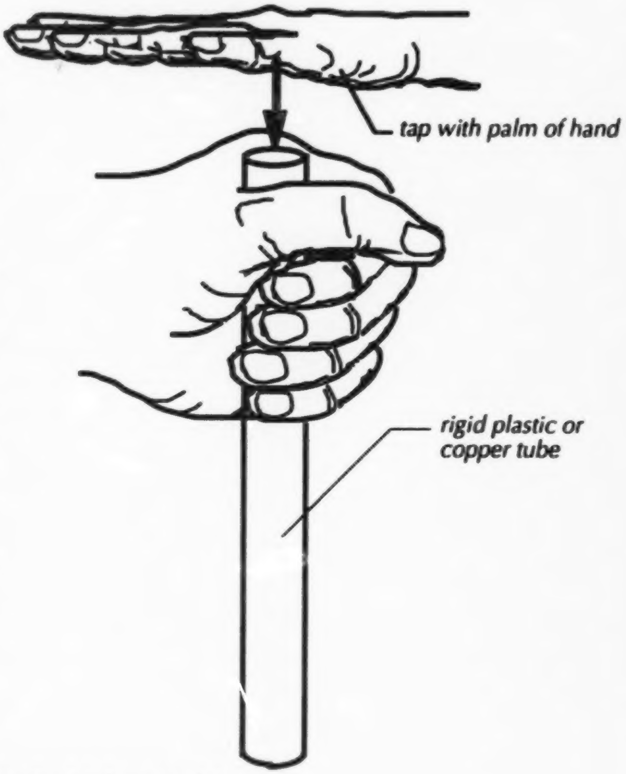
How to explain it:

The air flows from the stationary end to the circling end, because the air flowing past the moving end of the tube reduces the **air pressure** **(Principle of Bernoulli** -see chapter on flowing air). As the air flows along the corrugations of the tube, it starts to **oscillate.** The corrugations determine the frequency of the oscillations and thus the tone. The faster the air flows through the tube, the easier the **higher frequency harmonics** are excited, thus producing the higher harmonic tones.

The pitch is also determined by the length of the twirling tube. The shorter the tube the higher the pitch. With a little practice in slowing down and speeding up the twirling, the sound of a bugle can be easily imitated.

2.7.17. THE TWO-NOTE TUBE

What you need: 1. A length of rigid plastic or copper tubing (2-1/2" or 8 cm diameter, 1-1/2' or 50 cm long).


tap with palm of hand
rigid plastic or copper tube

How to do it:

1. Hold the tube with your right hand vertically and tap the top end with your flat left palm (hold the palm against the tube): a certain tone is produced.
2. Now tap the top end of the tube with the flat of your left hand palm and release the contact with the tube immediately after the tap; in other words: move your hand immediately away from the tube (it is like tapping the tube very lightly): another note is produced.
3. Keep alternating the two kinds of taps and let the students try to distinguish the two notes.

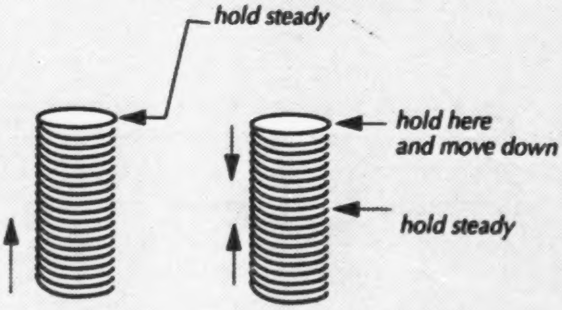
What to ask:

1. How was the tone in the tube produced?
2. Which of the two tones produced had a higher pitch?
3. How are the two tones or pitches related to each other?
4. What type of waves did we create with the two kinds of taps?

How to explain it:

By tapping the tube at the top end, a vibration of the air within the tube was created, producing a tone. When the palm is kept against the end of the tube, the wave is occurring in a tube with a **closed or fixed end,** producing a low tone. When the palm is tapped against the tube only lightly, the wave occurs in a tube with **open ends,** producing a tone an octave higher.

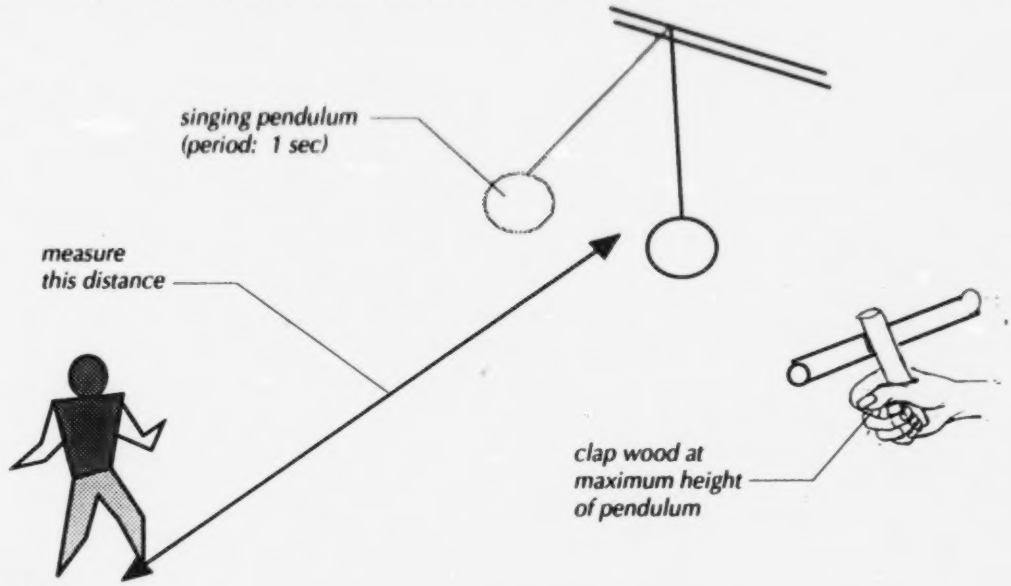
This can be illustrated by holding a short slinky vertically at the top only (closed end wave), or in the middle and moving the top faster (open end wave - see sketch on the right).



2.7.18. MEASURE THE SPEED OF SOUND

What you need: 1. A bright colored ball and string.

2. Two pieces of wood (to make a clapping sound).
3. A long measuring tape (or long rope and a short measuring tape).



How to do it:

1. Make a pendulum from the bright colored ball and string, such that it swings a full period (back and forth) within one second (by adjusting the length of the string).
2. Take the class (student) out to an open field (it should be 170-180 m long), attach the pendulum to a horizontal bar or tree branch and have one student clap the two pieces of wood together at the exact moment that the pendulum reaches the highest point of the swing.
3. Have another student stand next to the one clapping, to keep the pendulum bob swinging (by giving it a reinforcing push).
4. Once the clapping and swinging are synchronized, let the rest of the students walk back from the pendulum while observing the swing and listening to the clapping (soon the taps will get out of phase with the swings, and slowly get back in phase with the swings).
5. Stop moving away from the pendulum, as soon as the taps are synchronized again with the swings of the bob, and measure the distance from where you are now to the swinging pendulum.

What to ask:

1. Why was there a lag created between the taps and the swings?
2. What made the taps became synchronized again with the swings?
3. How can we calculate the speed of sound from the data?

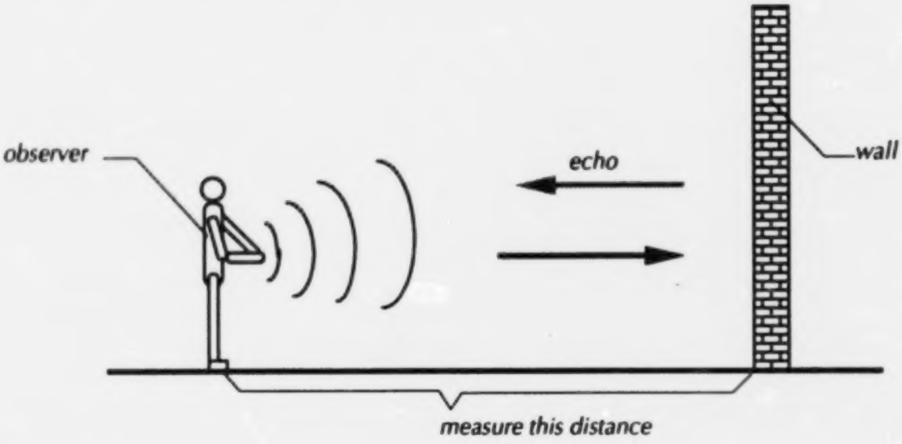
How to explain it:

As the period of the swinging pendulum was one full second and the tapping of the wood was at each maximum height of the bob, the claps were 1/2 second from each other. The distance from the observer to the pendulum (170 m) divided by the time (1/2 second) would be the speed or velocity of the traveling sound (340 m/sec).

2.7.19. THE ECHO SPEED CALCULATOR

What you need: 1. Two pieces of wood (to make a clapping sound).

2. An open space and a large vertical flat surface outdoors (such as a high wall of the school building or side of the house).



How to do it:

1. Take the class (student) outside to the side or back of the school building or house.
2. Start from about 20 meters from the wall (facing the wall) and move very slowly backwards while clapping with the wood pieces.
3. As soon as an echo of the clapping sound can be detected by someone, stand still and double check whether indeed an echo can be heard.
4. If indeed an echo can be heard, measure the distance from the observer to the wall.

What to ask:

1. How can we calculate the speed of sound in this event?
2. Could we start the clapping by approaching the wall from further out?
3. Why do you think we cannot hear an echo when we are too close to the wall or vertical surface?

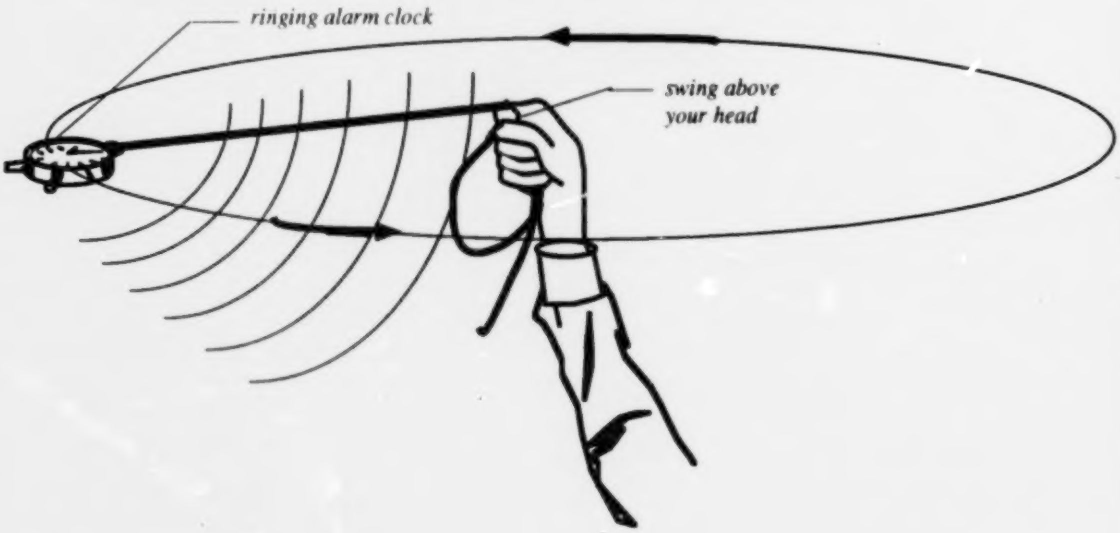
How to explain it:

The **minimum time interval** that the human ear can detect between two claps is 0.1 second. When this interval between the clap and the echo is shorter than 0.1 second, no echo is heard. This is why no echo is heard when we stand too close to the wall. By moving slowly backwards away from the wall, an echo will be heard at a certain moment. At this moment the echo came back within 0.1 second, the distance between observer and the wall is measured (about 17 m), and the speed can be calculated from: distance sound traveled (2 x 17 m = 34 m) divided by the time (0.1 sec) equals 340 m/sec.

When the speed of sound is already known, an approaching storm's distance may be estimated by counting the seconds between the lightning and the thunder, and multiplying this by the speed.

2.7.20. HEAR THE DOPPLER EFFECT

What you need: 1. A small alarm clock (with a bell sound and handle on top)
2. A piece of strong (nylon) string - about 2 m (6 ft) long.



How to do it:

1. Tie the end of the string to the top handle of the alarm clock.
2. Set the alarm off, grab the other end of the rope and swing the alarm clock above your head. (Make sure you have enough room to swing the clock around)
3. Listen carefully to the pitch of the alarm clock. Does it stay the same?

What to ask:

1. Why did we hear two different pitches of the bell?
2. Was the clock moving away or coming towards us when we heard the higher pitch?
3. What would we hear if we swung the clock faster around?
4. How would the pitch change if we used a longer string?
5. What examples can you name in daily life where this particular effect can be experienced?

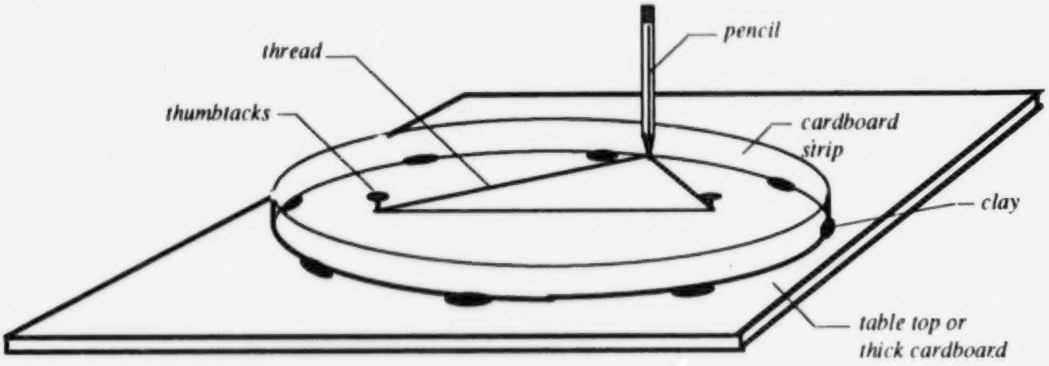
How to explain it:

The pitch of a tone that we hear is determined by the **frequency** or number of waves that reaches our ear drum. The more waves or the higher the frequency of sound, the higher the pitch. When the alarm clock is swung above our head, it moves away or comes towards us. When it comes towards our ear drum, more waves reaches it so that we will hear a higher pitch. When the clock moves away from our ear, fewer waves reaches our ear, and so we hear a lower pitch.

This principle was discovered by **Christian Johann Doppler** in 1842. It is being used in astronomy to determine how fast the earth is rotating around the sun among others. In the field of radar, it makes it possible to do speed checks on the highways. The **Doppler Effect** can be experienced when driving in a car and another on-coming car passes by while the horn is on continuously. When sitting in a train sometimes we can also hear the higher pitch of another on-coming train's whistle and as soon as it passes by us, we hear a lower pitched whistle. This same effect is heard when a fire siren from a fire station is on: a higher and lower pitch is heard alternatively with a constant period. This happens because of the horn of the siren which rotates on top of the fire station with a constant speed. When the horn turns towards us we hear the higher pitch, and when it turns away from us, we hear the lower pitch.

2.7.21. THE ELLIPTICAL WONDER

What you need: 1. Two thumbtacks, a pencil, and a marble. 2. A thick thread or thin rope. 3. A smooth table surface or large cardboard. 4. A long 3 cm wide cardboard strip and molding clay.



How to do it:

1. Press two thumbtacks about 30 cm apart in the cardboard or table top (this can be closer or wider apart depending on the size of the surface area of the table or cardboard).
2. Make a loop with the thread, where the total length of the thread is 5-10 cm longer than twice the distance between the thumbtacks.
3. Hold this loop of thread tight between the thumbtacks and the pencil tip (holding the pencil vertically) and describe a perfect ellipse with the pencil on the cardboard.
4. Build a wall with the cardboard strip and the molding clay on this ellipse by pressing blobs of clay between the strip and the table (or cardboard).
5. Roll a marble from one focal point (thumbtack) in any direction to the elliptical wall. Which way does it bounce back?

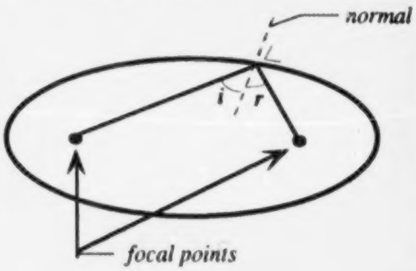
What to ask:

1. Why does the marble always bounce back to the other thumbtack?
2. What points are the thumbtacks in the ellipse?
3. How large an ellipse can be constructed this way?
4. How would sound or light waves bounce off the elliptical wall?

Explanation:

The reason why a perfect ellipse results by keeping the thread tight between the two focal points and the pencil is, because the sum of the two radii stays the same.

Another feature of the ellipse is that the **angle of incidence** (i) of one radius is the same as the **angle of reflection** (r) of the other radius (see Sketch on right). This makes it possible that softly spoken words in one focal point can be heard at another focal point quite a long distance away from the first focal point.



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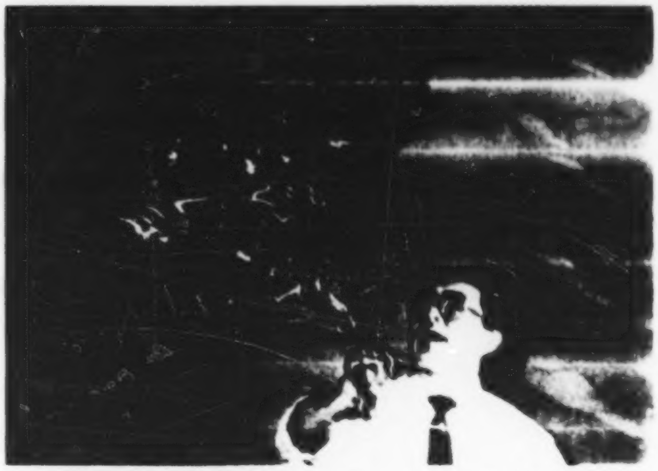

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